Understanding Megacities with the Reconnaissance, Surveillance, and Intelligence Paradigm

Topical Strategic Multi-Layer Assessment (SMA) and U.S. Army Engineer Research Development Center (ERDC) Multi-Agency/Multi-Disciplinary White Papers in Support of National Security Challenges

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Abstract:

Traditional DOD information collection techniques are not robust enough to understand the rapidly changing urban environment in very large urban areas. Developing world megacities are especially difficult to monitor due to large migration in- and out-flows causing quickly changing population as well as the urban dynamics that increase as population grows. Given the challenges of declining DOD budgets while improving our ability to monitor megacity populations, the chapters in this white volume describe many of the issues facing the DOD for phase zero operations and collecting the information necessary should conflicts escalate. Most of the chapters' discussions are heavily influenced by LTG Flynn et al.'s "Left of bang: The value of socio-cultural analysis in today's environment" PRISM article.[1] "Left of bang..." was also revised and included in "National Security Challenges: Insights from Social, Neurobiological, and Complexity Sciences," available at http://www.nsiteam.com/publications.html.

This White Volume builds on top these research efforts with a particular focus on monitoring and surveillance research in complex urban environments. The target audiences are planners, operators, and policy makers. With them in mind, the articles are intentionally kept short and written to stand alone. All the contributors have done their best to make their articles easily accessible.

[1] Flynn, M., Sisco, J., Ellis, D. (2012). "Left of Bang: The Value of Sociocultural Analysis in Today's Environment,"*PRISM*, Vol 3(4), pgs 12-21.

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Preface

Lieutenant General Michael T. Flynn, Director, Defense Intelligence Agency

The nature of global conflict is ever-changing, and a clear understanding of the threat environment is critical to the mission success of our policymakers, diplomats, and warfighters. A few clear trends are emerging to transform the operational environment. Formally declared warfare among nation-states is becoming less likely while the potential for conflict ignited by violent transnational and sub-state actors grows. A rapidly growing and free-moving global population, the growth of urban areas in underdeveloped countries, and expanding access to transformative technology pose new and unforeseen challenges for both our allies and our adversaries. Meanwhile, the fragility of certain states in the Middle East, Africa, and Asia require us to better detect the precursors to political, social, and economic unrest across the globe. And importantly for this collection of white papers, in the future, our forces are more likely to operate in an urban battlespace than in the mountains, jungles, and deserts of past conflicts. This changing world requires a studied understanding of the global population shift and its impact on conflicts of the future.

Global Population Growth Fueling Megacities

The world's population is growing at an unprecedented rate: in 2010 the global population hit 6.7 billion, and it is forecasted to reach 10 billion by 2050. To put this growth in historical perspective, global population just surpassed the one billion threshold in 1804. The most concentrated areas of this growth are located in what social scientists term "megacities," or cities with more than 10-million people. According to the Population Reference Bureau, we are experiencing an urban demographic revolution: in 1980, there were three megacities in existence – today, there are 24.[1] By the middle of the 21st century, the urban population will almost double, increasing from approximately 3.4 billion in 2009 to 6.4 billion in 2050.[2]

The potential for new sources of instability is enormous; the sheer population growth within megacities overtaxes already-stressed governance capacity, resource availability, and infrastructure, making these urban areas the center of mass for many of the world's conflict-prone regions. U.N. projections to 2025 suggest that future megacity population growth will be by predominantly lower-income people, primarily in Africa and South Asia.[3] In these new and fast-growing megacities, the government's ability to provide basic services often cannot keep pace with the growing needs and demands of the populace, resulting in an expectations gap and potentially a feeling of hopelessness that can further stoke violent conflict.

Of course, not all megacities are hotbeds of unrest: cities like New York, Shanghai, and Tokyo continue to serve as engines of economic growth for their respective

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[1] http://www.prb.org/Publications/Articles/2000/TheUrbanDemographicRevolution.aspx

[2] World Health Organization- Global Health Observatory: http://www.who.int/gho/urban_health/situation_trends/urban_population_growth_text/en/

[3] http://www.forbes.com/sites/joelkotkin/2013/04/08/the-worlds-fastest-growing-megacities/

countries, providing opportunities for migrants of varying skill levels to find jobs in manufacturing and the service industry.[1]

Economic and Environmental Challenges

In order to begin to understand the complexity and the sustainability of individual megacities, we must assess two critical factors: the economy and the demographic environment.

Dismal Economic Prospects

Measured growth and sustained economic opportunity is critical to the life of a megacity. According to the World Health Organization (WHO), more than one million people migrate to cities each week. Today, the most rapid demographic growth is taking place in countries with relatively young populations, where poor employment prospects for a growing youth bubble leave many without options and desperate for any means to support themselves. As more people flood these urban agglomerations, energy demands overwhelm infrastructure and water requirements exceed supply, creating an overstressed life-support infrastructure and, eventually, conflict over basic human needs. Displaced by abject poverty, natural disasters, and/or civil unrest in their rural homelands, the most vulnerable segments of the population concentrate in the peri-urban slums surrounding megacities. In these pockets of destitution, often devoid of the institutional frameworks necessary for effective governance and rule of law, they are ripe for recruitment and radicalization by internal dissidents and violent non-state actors.

A Rapidly-Shifting Demographic Environment

The global growth of megacities also presents new challenges in mapping the socio-cultural composition of urban populations – a critical component to understanding the unique mindsets of rural-to-urban migrants – and gaining the cooperation of diverse megacity populations. Challenges, such as forced migration due to sprawling urban development and a lack of decent water and housing, quickly shift the demographics and dynamics of a region. Sudden changes can exacerbate socio-economic inequalities and fuel conflict, as new populations enter already-occupied areas and compete for existing resources.

Implications for U.S. National Defense

The convergence of these factors has the potential to threaten stability on a regional scale. In this environment, the Intelligence Community (IC) will need to take on an increasingly critical role by helping policymakers anticipate instability and, in situations where we cannot overcome these shortfalls, determine and set conditions appropriate for defense planning. Traditional Department of Defense information collection techniques, however, are no longer robust enough to respond to such rapidly changing urban environments. Increasing demand coupled with a declining defense budget requires a renewed look at the structure and direction of our intelligence collection techniques and processes.

[1] http://www.prb.org/Publications/Articles/2000/TheUrbanDemographicRevolution.aspx

Four factors will be crucial to the IC's success in this shifting environment:

- **Enterprise Agility:** We must be structured and ready to rapidly respond to new threats at a moment's notice. This agility will include breaking down the stovepipes and information silos typical to large-scale bureaucracies and creating a more focused, integrated enterprise. Driving ourselves to increasing levels of integration, fusion, and intelligence sharing both internally and with our closest partners must be our way ahead.

- **Understanding the Environment:** If we learned anything over the previous decade of war, it is that a failure to recognize and accurately define the operational environment can lead to a mismatch between forces, capabilities, missions, and goals.[1] The dynamic nature of our new operational environment will require a fingertip feel and clear, in-depth knowledge of the political, social, cultural, and economic atmospherics related to each conflict.

- **Building Partnerships and Increased Burden Sharing:** As we face steadily increasing requirements in the face of continually diminishing resources, we must look to new avenues of engagement, even beyond traditional interagency cooperation, to maximize our reach. Regular engagement and collaboration with our partners and allies abroad must inform our strategic planning and influence how we think about new types of international conflict that require a broad range of mission capabilities not easily handled by one country on its own.

- **Technological Adaptation:** Emerging technology has the potential to enhance our security, but will also challenge our defense capacity in a variety of new ways. The exponential increase in the volume of data worldwide is staggering, and poses major challenges to the analysis and synthesis of intelligence. Information technology and social media now elevate local issues to an international stage. Greater connectivity facilitates worldwide connections between governments, non-state actors, and transnational threat networks both for better and for worse. We must continue to adapt and develop innovative methods appropriate for this dynamic environment.

The Way Ahead

DIA is transforming the structure and operational processes of intelligence collection, analysis, and production to provide strategic advantage for our nation.

- **An "Integrated Center" model for intelligence:** DIA's decade of wartime lessons learned demonstrate that the most successful teams integrate personnel from multiple intelligence disciplines to fuse intelligence and operations.[2] With this lesson as a blueprint, the agency has transformed its operating model to focus on

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[1] Joint and Coalition Operational Analysis, "Decade of War, Volume 1: Enduring Lessons from the Past Decade of Operations", June 15, 2012.

[2] Ibid. Also, the author was directly involved in establishing fusion centers in Iraq and Afghanistan (and elsewhere). These centers were highly integrated operations and intelligence interagency action arms for maneuver commanders and they proved their value on multiple occasions and the concept is now being applied in other regions of the world.

Integrated Intelligence Centers (IICs) that proactively network capabilities from across the Combatant Command Joint Intelligence Operations Centers and the entire Defense Intelligence Enterprise. This construct closely integrates our analysis, collection, and science and technology capabilities – together with embeds from our IC partners and a robust mission-support network – to provide support to defense customers from the tactical to strategic level.

- **Making the "edge the center":** We are enhancing the level of support and expertise we provide to warfighters and policymakers by increasingly placing our most valuable assets – our people – overseas and in direct support of those closest to the operating environment. We must continue to drive an expeditionary mindset throughout our workforce – a workforce that has extensive combat experience, including our civilians.

- **Leveraging new technology:** Improvements in technology allow for faster, flatter, increasingly-matrixed intel-ops teams to respond to requests and anticipate requirements from across the globe. These new tools, supported by appropriate policies and processes, make possible unprecedented levels of interagency and international collaboration on our toughest intelligence problem sets.

We don't need to reinvent the wheel. In this belt-tightening fiscal environment, we must identify additional ways to tailor current techniques to the dynamic environments of megacities and surrounding urban fringe. The following chapters in this paper identify many of the issues facing the Department of Defense and re-examine the reconnaissance, surveillance, and intelligence paradigm as it relates to megacities, including:

- How the physical environment impacts operations and contingency planning;

- Using an inverted RSI model as indicators and warnings of instability; and

- Tailoring modeling tools for predictive analysis.

This research is an example of how we need to work outside the traditional intelligence way of doing business to establish partnerships and knowledge-sharing across and outside the defense intelligence community. Only through a fully integrated process that includes collaboration among all of those with an interest in our nation's security can we meet tomorrow's challenges.

Introduction and Executive Summary

Dr. Charles R. Ehlschlaeger, Engineer Research and Development Center

The overriding goal of this White Volume is how to best understand the changing population, infrastructure, and environment in complex urban environments so that we can respond to both short- and long-term national security challenges. The SMA research project "Megacity Reconnaissance, Surveillance, and Intelligence Project: Dhaka Pilot" uses the term `Megacity' in its title to reflect the challenges of understanding rapidly changing urban environments. SMA chose Dhaka, Bangladesh for the case study because Dhaka is one the quintessential urban spaces that traditional DoD socio-cultural techniques would find most challenging to understand. Dhaka is one of the fastest growing cities in the world, a megacity with no indication that its growth rate will decline.

This White Volume explores issues relevant to understanding urban populations, both today and years from now, and the stability indicators that will help to monitor insecurity and prevent potential crises around the world. While the U.S. Government has long monitored the stability of other regimes, it does not have a long history of extensively monitoring other populations except when U.S. troops are deployed overseas. For example, the South Vietnamese military and the U.S. Army works side-by-side extensively measuring and monitoring populations in rural areas prone to Vietcong activities. This very labor intensive survey was stored in a database management system and quantitatively analyzed. It was statistically shown that the collection and use of this database reduced violence in areas with data collected compared to similar areas not monitored. Monitoring populations using human terrain teams or U.S. and Partner Nation military units, however, is both risky and labor intensive. Thus, existing population monitoring in Afghanistan and Iraq cannot be performed across the entire globe due to their costs. It is necessary to change the way we collect, integrate, and disseminate population information to achieve short- and long-term national security goals.

The White Volume's authors represent practitioners and researchers with extensive experience in their respective fields. While we were unable to include all the experts desired for this effort, the White Volume contains a broad spectrum of perspectives for better understand urban environments. The chapters are organized from the more theoretical and philosophical to the more technical. The following brief description of these papers provides an overview of each chapter, but doesn't express all the content contained within.

Dr. James Knotwell's "Megacity Place-Centric Population Analysis" begins the White Volume with a discussion on the need for cultural understanding in RSI using the "Fundamental Four" cultural descriptors. He points out the Fundamental Four doesn't account for the "analysis of place", or how geography affects culture. Dr. Knotwell discusses in detail how socio-cultural analysis could be improved by better understanding of geographic analysis of place.

Next, Marc Imhoff et al.'s "Evaluating Long-Term Threats to Environmental Security via Integrated Assessment Modeling of Changes in Climate, Population, Land Use, Energy, and Policy" chapter discusses regional environmental security forecasting energy, water scarcity, and climate changes far into the future.

In the third chapter "Understanding Megacities-RSI – Dhaka's Design as an Expression of Culture & Politics," Dr. David Ellis and James Sisco explore the socio-cultural dynamics of Dhaka, Bangladesh from the community level, mahallas, upwards to better understand instability indicators. The chapter discusses the tension between political, religious, and social aspects of the unplanned megacity.

Douglas Batson's chapter on land tenure and property rights in megacities discusses rural-to-urban migration and the piratical power grabs associated with slum formations. It examines ungoverned urban spaces and the process of building human security by improving poor peoples' hold on land. Finally, the chapter discusses three tools that will aid in identifying and understanding who occupies and controls megacity spaces.

In the fifth chapter, "Urban Socio-Cultural Monitoring with Passive Sensing," Michael Farry et al. propose that passive sensors located in difficult to assess urban environments will provide actionable intelligence in local or tactical situations. The authors analyze how various measurable social signals can be applied to PMESII variables. The use of small sensors, while potentially problematic if used in phase zero environments, could provide valuable information in ungoverned urban spaces when supported by partner nation governments.

While other chapters in this White Volume discuss ways to represent populations geographically or culturally, Randy Pearson's "A Network-based Approach to National Security" raises the challenges of understanding illicit financial networks. Pearson discusses the trans-dimensionality of illicit networks, and the difficulty of representing this information for DOD operational planning. The complexity of financial networks is not an uncommon one for socio-cultural analysis. Socio-cultural systems cannot be easily represented in any of the traditional quantitative visualization methodologies (I.e., thematic maps, topographic maps, networks) because the number of dimensions of socio-cultural factors is greater than what can easily be readily seen.

In Chapter Seven, "Evaluating Slum Severity from Remote Sensing Imagery," Dr. Karen Owen discusses original research demonstrating remote sensing techniques that will help identify neighborhood-scale socio-cultural information in urban areas, especially economic variability. While the techniques require calibration for each megacity, the research provides excellent direction for experienced remote sensing professionals.

Chapter Eight, "Modeling the Discourse of Megacities: Assessing Remote Populations in the Non-Western Worlds," Dr. Kalev H. Leetaru & Dr. Charles Ehlschlaeger discuss the ramifications of collecting information from the internet in order to understand megacities. They argue that while megacities have unique geographic and social characteristics, the tools and techniques for understanding communication remain the same but that additional foundational information will ease the difficulty of monitoring urban areas in the RSI paradigm.

Chapter Nine, "How Semi-Automated Analysis of Satellite Imagery Can Provide Quick Turn-Around Economic and Environmentally Relevant Answers to Large Scale Questions", by Ms. Ida Eslami et al., provides a technical discussion on research that can greatly benefit the RSI paradigm. The goal of their research is to develop techniques for taking satellite imagery and processing it to actionable information. Their technique mainly uses MODIS satellite products updated every 16 days in order to monitor changes and trends over time. Possible socio-cultural applications include urbanization, crop abundance & predicted yields, and the availability of natural resources. Given the challenges of monitoring megacities around the world in phase zero, automated techniques will be necessary to derive information from the copious amounts of data collected from satellites and the internet.

The final chapter, "UrbanSim: Using Social Simulation to Train for Stability Operations," Ryan McAlinden et al. discuss modeling urban environments for training. Social and cultural modeling plays a critical role in advancing our situational understanding of these complex, interwoven environs. Academia, government and industry all continue to make advancements in developing accurate models of human behavior, though significant challenges still remain. These challenges are presented in the context of an existing training application for teaching Battalion commanders how to successfully navigate complex, multifaceted missions where the populace is the cornerstone to success.

Chapter One, Megacity Place-Centric Population Analysis

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Abstract

The elements of place-centric population analysis are explained in the context of how they inform and improve the Reconnaissance, Surveillance, Intelligence (RSI) methodology. The author agrees that RSI's "Fundamental Four" describe culture in the most useful way for enhancing Wide Area Security mission accomplishment through pertinent Socio-Cultural Analysis (SCA), but explains how place attributes of the homes of megacity immigrants infuses their cultural formation and thus must be considered in understanding the cultural transformation ongoing in megacities as urbanization intensifies cultural tension attributable to that transformation. It is suggested that place-centric population analysis contains the additional quality of contributing to an SCA "baseline" for streamlining cultural analysis from megacity to megacity, through knowledge of immigrant origin formational attributes associated with those types of home places provide a generalizable starting point for analytical expectations from which initial inferences can be made that particular observations and experience over time will adjust.

Keywords

Needs, satisfiers, Great Modern Cultural Transformation, traditions in tow, traditions in place, traditions in flux, cultural baseline

Introduction to RSI

Reverse ISR, or Reconnaissance, Surveillance, Intelligence, a.k.a. the RSI Approach to Socio-Cultural Analysis (SCA), purposely reverses the well-established ISR form of "intel"-collection and analysis. The reversal is intended to distinguish SCA's aim as different from that of gathering "intel": where the object of intelligence is mostly targeting, the object of SCA is cross-cultural comprehension (CCC) for intervention effect, explanation, and expectation. The incorporation and/or expansion of SCA into the military decision making process (MDMP) has become more critical for the intelligence community in general because military operations are gradually changing. Since SCA, with the onset of Irregular Warfare (IW), is needed more now than before, the RSI approach intends to support and advance the increasingly more prevalent Wide Area Security (WAS) mission over Combined Arms Maneuvers (CAM), where ISR reigns supreme. An RSI-derived understanding of culture in both a broader and deeper sense is WAS mission critical.

The Geography of Culture

The formulators of the RSI-SCA approach (Puls & Ellis, 2011) recognized that cultural understanding requires some form of population-centric analysis so that culture can be reduced to its more fundamental components. The analytical goal is to answer "why" people do what they do to satisfy their needs—the very essence of culture—thus, adding operational value to WAS intervention strategies and mission goals. To that end, the aptly-termed RSI "Fundamental Four" cultural descriptors—Ontology, Identity, Logics of Appropriateness, and Narrative—emerge to organize culture-specific objectives, methods, and relevant interpretations (Puls & Ellis, 2011). It is relevant to our purpose to point out that none of these four categories explicitly addresses the contribution of place to cultural formation, yet place is an essentially important formational factor. Place-Centric population analysis, the subject of this treatise, "grounds" the RSI Fundamental Four by forcing consideration of those physical, material, and geospatially situational place attributes that fundamentally affect cultural evolution over time in that particular place: in other words, what is, 1) materially available for those people in that place to find, identify, use, and adopt to satisfy needs, or 2) the physical limits or material parameters within which successful cultural adaptation strategies and outcomes must occur there.

How Place Forms Culture

Populations exhibit cultural expression and behavior *in part* because of the collective effect of their various, multiple, and simultaneous permutations of personal and social attitudes, aptitudes, inclinations, and dispositions. These are important but they are not the only formational forces that matter, they contribute no more to ultimate cultural formation than do those characteristics of the places those populations inhabit: particular places that provide all that is *materially* required to satisfy the needs ALL populations must address. For the purpose of clarifying how place figures in to an understanding of a people's culture—again, defined as what they DO to satisfy their needs—a distinction must be made between NEEDS and SATISFIERS of needs. All people, everywhere and always, have the same set of needs. Paul Ekins, in an earlier work (Ekins, 1986), uses only nine categories to delimit what those are, and always have been, for all us who've ever lived and ever will live on Earth: permanence, protection, affection, understanding, participation, leisure, creativity, identity, and freedom. That's it, finite and, both, spatially and temporally constant. But *satisfiers of needs*, those substances, technologies, and artifacts that are used to form culture—food, water, housing, building material, routes, social systems, contracts, religions, etc.—vary widely over the face of the earth in type, quantity, and quality as dictated by previously energized physical forces and geospatial arrangements of material substances, in addition to population aptitudes and ideals.

Groups of humans who choose, by proximity, heritage, and experience, to constitute themselves as a people with their own ways of thinking and acting, have only those things to use for doing it that they encounter in the place they inhabit, or those things that flow through from other places in accordance with how their place is situated among others. Geospatially inherent patterns of mobility there matter, too, which are also heavily influenced by physical forces and material landscapes. In short, landscapes are radically different from place to place, yielding different items for use in satisfying needs, and building traditions and cultures. Sometimes, even over a small distance or short time, the physical and material attributes will change markedly: humid to dry, steep to flat, soil to no soil, minerals to no minerals, cold to warm, generally light to generally dark, and so on. Mobility will be influenced by "paths of resistance" represented in "desert trails," rivers, hills, seas, etc. People in semi-arid regions will *necessarily* value, for example, what little water and patches of soil they have at their disposal, more than people inhabiting a humid, flat interior plain. Different materials requiring different utilization technologies will *necessarily* be preferred. People on ocean coastlines or situated along navigable rivers will *necessarily* and more frequently encounter others from other places and likely be less suspicious of such encounters than relatively remote societies.

In short, hill people, for example, are noticeably different from flatlanders; arid people are noticeably different from plains agrarians; tundra and seasonally temperate folk are noticeably different from tropical islanders and rainforest denizens, and so on. *Where* people are is at least as important as *who* those people are, especially in determining how they live, and how "tolerant" they are with everyone else not like them; which is what we, the SCA community, fundamentally want to understand, and which the RSI Fundamental Four approach analytically addresses.

For our purposes, then, analyzing populations to discern how their culture influences their behavior in somewhat predictable ways, demands that we understand as much as we can about *where they were when they became a people, and how they used that place to satisfy their needs*; especially now that they are moving from those typically rural places to more massively-concentrated urban places—Megacities. That people-shift constitutes the Great Modern Cultural Transformation that is occurring now and will continue in the near future, consisting of urbanization rates transcending all recent experience. As we've seen over the last few decades, and at an accelerating pace of late, increasingly mobilized groups of people are, in individual units, testing their own capacities for adaptation in largely unknown, increasingly congested, and politically intense megacities. They bring with them their own cultural ways of thinking and doing as formed in those places they originated, by the attributes of those places—maybe riverside, maybe mountainous, maybe coastal, maybe hot, maybe sprawling, maybe something yet different in more ways than one. These peoples exert their unique, unfamiliar influence on cultural adaptation to the institutions and behaviors in those neighborhood destinations they seek, resulting from an inevitable, close proximity clash among the traditions those immigrants bring with them, the traditions already developed in that city before they got there, *and* those traditions evolving from the constantly changing rural/urban ethnocultural admixtures: in other words, the inevitable and potentially volatile clash of *traditions in tow (rural) v. traditions in place (urban) v. traditions in flux*. Urbanization complicates cultural evolution and expression, and megacity culture is anything but simple; to an intense degree it belies prediction, place-centric population analysis represents a viable attempt to identify explanations and generalities that alleviate some of this analytical and predictive uncertainty.

Analytical Utility and Relevance

Place-centric population analysis of migrant's cultural origins provides a starting place for understanding how those were before the shift, once located anew in an unfamiliar place, thus also providing somewhat of a cultural "baseline" generally applicable to certain peoples of common geospatial "upbringings": mountain cultures, for example, demonstrate certain traditional generalities that apply across specific mountain ranges, desert people, plains cultures, tropical tribes, and tundra people, likewise. There are, of course, many specific traits that distinguish these cultures from each other, that must ultimately be examined and interpreted, but cultural place qualities often provide an analytical starting point from which frameworks can be formulated and inferences put forth in advance of the meticulous observation and actual experience required for more sophisticated, intricate, and nuanced comprehension gradually forming with time.

But how do you do it? Place-centric population analysis simply consists of a set of material/physical/situational explanations for the formation and/or transformation of observed cultural traditions within the RSI methodological spectrum: Ontologies, Identities, Logics of Appropriateness, and Narratives. Urban Political Ecologists and Urban Geographers, among others, are adept at featuring these kinds of prevalent, inherently geo-spatial, explanations for evolving cultural behaviors and disruptions in both the cultural origins of megacity inhabitants, and the "contested landscapes" within which the modern urban cultural transformation is occurring. Place-centric population analysis examines the formational impact of relative quantity (abundance v. paucity), type, and quality, of such phenomena as stocks and flows of life essentials, like water, soil, nutrients, and energy, plus other pertinent value chain relations and economic throughput streams associated with transactions in these materials and their wastes.

The RSI-SCA methodological intent is to "discern, track, and influence cultural changes [by] deconstruct[ing] [them]…in order to analyze how different social forces animate or are constrained by a population's *ontology*, how the forces activate or seek to create *identities*, how they make use of *logics of appropriateness* to activate the norms and values that privilege the 'rational' behavior they desire, and how *narratives* create or reinforce the ideational space the social forces desire" (emphasis in original) (Puls & Ellis, 2011). These are, in my opinion, precisely the correct cultural items to discern for population cultural analysis, *place-centric* population analysis only demands an additional caveat attach to the end of that statement to the effect of: "and how each forms and are formed by the physical, material, and geo-situational attributes of the places they occupy, use, and call home."

Cultural ontologies consist of that set of ideas and paradigms that those people "'know' to be real, and understanding, for them, of how the world 'works' " (Puls & Ellis, 2011). They know these, in substantial part, because of what they've learned to do in *their* home landscapes to flourish. Cultural identities are how a particular constituted group of people distinguish themselves from others in terms of "interests, social priorities, norms, and values" (Puls & Ellis, 2011), each of which are derived from their traditional home experience: it's why people are asked, upon meeting other people, where they are from . . . because it matters. In a similar sense, cultural narratives, how people define, refer, and attach meaning to things, and the establishment of appropriate parameters to govern behavior, derive also from trials and errors of living in a particular place with its particular set of artifacts that result in traditions that work for them there.

Conclusion

Learning how each of these derives from home experience and comparing these to traditions of others from places that are similarly dry/wet, steep/flat, central/remote, etc., allows analytical generalities to be identified for each "class" of cultural home origin. These generalities contribute to a "cultural baseline" for facilitating the advancement of cross-cultural comprehension: humid, steep, remote places, for example, tend to form cultural traditions within a certain set of parameters.

The cultural clash of rural folk from all sorts of home territories and the cultural baggage they carry with them as they move to new, densely settled megacity neighborhoods, and the inevitable tension that derives from being forced to operate, mostly unfamiliarly, in these new places, with new rules and new traditions, is the reason we are interested in what is happening as the modern urban cultural transformation presses on. Following the RSI-SCA protocol, with special attention paid to explaining its categorical variables—ontology, identity, logic of appropriateness, and narrative—from the perspective of how the characteristics of home contributed to their ultimate formation and expression, is the essence and relevance of place-centric population analysis.

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Chapter Two, Evaluating Long-Term Threats to Environmental Security via Integrated Assessment Modeling of Changes in Climate, Population, Land Use, Energy, and Policy

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Abstract

Environmental security will require the consideration of the physical environment when setting forth operations and contingency planning to maintain Phase 0 conditions in the future. Modeling tools of various scales, such as the Global Change Assessment Model (GCAM) and Regional Integrated Modeling and Analysis (PRIMA) platforms, provide methods for building scenarios to evaluate future conditions and potential unintended consequences that may arise from the complex interdependencies of human and earth systems. These models allow simulations that elucidate the interdependencies between sociopolitical, energy, and climate stresses on varying spatial and temporal scales. They provide methods to project future scenarios and the sensitivity of resources critical to regional stability, such as food prices, energy availability, and water resources. Metrics and indicators may be derived through modeling scenarios that support intelligence, surveillance, and reconnaissance (ISR) planning scenarios that must consider future operating conditions in megacities, such as changing energy demands that stress electrical grids, increasing food prices, and tradeoff decisions for competing water usage.

Keywords:

Integrated Assessment Modeling, Environmental Security, Policy, Climate Change, Building Energy Demand, Impacts, Population Dynamics, Food Security, Water Scarcity

Megacities in Context – Global Threats to Environmental Stability

Several directives from Flynn (2012) were captured to reorganize the approach and methods for dealing with future threat scenarios. He stressed the need to consider the physical environment when evaluating the fragility of peace. This concept is coined environmental security. LTG Flynn stressed the need to think beyond the historical threats to U.S. security, such as emerging nuclear powers, and consider both human and earth systems when planning for sustainment of Phase 0 conditions under changing climate conditions. The interdependent nature of megacities highlights the criticality of focusing crisis mitigation actions on economic, diplomatic, and ecological components, not just military solutions. Intelligence, surveillance, and reconnaissance (ISR) should consider climate change impacts on these components as potential precursors for future conflict as environmental security in megacities becomes increasingly difficult because large populations and resource demands are concentrated in a small footprint. LTG Flynn concluded that understanding these components will enable more effective diplomacy and better-focused military activity to keep many budding conflicts left of bang.

More than half of the world's population lives in cities today and by 2030 this proportion will likely reach two-thirds. Twenty-seven cities have reached megacity status, and this number will continue to grow. While megacities such as New York, London, and Tokyo have the means to manage themselves, those that have emerged in the last half-century have passed the "tipping point," becoming overwhelmed, dangerous, and often ungovernable (Liotta and Miskel, 2012). An understanding of the future of megacities and the stressors that may be applied to them requires an understanding of the interactions between human and earth system stresses. Urbanization is taking place within broader-scale processes that include socioeconomic, demographic, and technological factors. These stressors are global in scale, express themselves regionally, and are influenced deeply by political stability, policy, and trade. New megacities will be formed and older megacities transformed within this milieu and the communities will be shaped by these overarching factors as the global competition for the resources and capital needed to cope with these changes accelerate influenced in part by climate change.

The factors contributing to the overall societal risk of disruptions associated with changing climate conditions include event severity, exposure and vulnerability of people or critical systems, and the adaptive capacity or inherent resiliency of these systems. Exposure and vulnerability are functions of both the direct effects of a climate event and the second- or third-order effects, which are mediated by globalized systems. Therefore, the security risks cannot be predicted by looking only at climate trends and projections. Changing sentiment and policy decisions required for mitigation or adaptation occur at megacity scales, but reverberate throughout the global system. Unintended consequences such as a pro-biofuel policy in the U.S. that may drive up the cost of food globally must be evaluated using integrated assessment (IA) models. These models allow consideration of the synergistic impacts of policy and climate that may destabilize megacities as seen by recent brownouts, blackouts, water shortages, rising food costs, higher temperatures in the urban heat islands, increased air and water pollution, and impacts on human health.

The U.S. Intelligence Community (IC) has already recognized climate change as a threat multiplier in already-volatile regions and in those that are currently stable. An IC-commissioned report by the National Research Council (NRC 2012) concluded that, "We know beyond reasonable doubt that the consequences will be extensive." It states that "Given the available scientific knowledge of the climate system, it is prudent for security analysts to expect climate surprises in the coming decade, including unexpected and potentially disruptive single events as well as conjunctions of events occurring simultaneously or in sequence, and for them to become progressively more serious and more frequent thereafter, most likely at an accelerating rate. The climate surprises may affect particular regions or globally integrated systems, such as grain markets, that provide for human well-being."

This chapter illustrates how IA modeling and research are used to simulate how the interconnections between sociopolitical, energy, and climate stresses will express themselves in various sectors important to the functioning of megacities. The goal of IA modeling is to bring together the key factors that influence global change in a single modeling framework, allowing a self-consistent exploration of their interactions. Done properly, IA modeling can retain the influence of global interactions while simultaneously simulating and exploring regional or sectoral outcomes. The remainder of this chapter provides example outputs from the Global Change Assessment Model (GCAM) that support ISR planning scenarios that consider future operating conditions in megacities, such as changing energy demands, increasing food prices and security, and tradeoff decisions for competing water usage.

Global Change Assessment Model (GCAM)

IA models, such as GCAM, are the world's preeminent tools for integrating components of economic, energy, terrestrial, and climate systems in order to understand drivers of greenhouse gas emissions (GHG) and consequences of climate change mitigation policy options. GCAM is dynamically capable of integrating these interdisciplinary forces that act upon megacities at spatial scales ranging from local to global and over temporal scales operating from decadal to the immediate. The Pacific Northwest National Laboratory has developed and maintained GCAM for over 30 years and supported both private industry and government scenario development. The scenarios support strategic research and decision science on interdependencies between energy, technology, policy, and climate change. GCAM is designed to allow analysts to explore how regional and national economies might respond to climate change mitigation policies including carbon taxes, carbon trading, land-use regulation, and accelerated deployment of energy technology. With a simulation period extending from the present to the end of the century at 5-year intervals (1-year time step in development), GCAM can explore these interactions from an operational scale to a more strategic, long-range forward operating scale.

A particular strength of GCAM is that it was designed to be differentially scalable. That is, it was designed to link large-scale phenomena such as global agriculture and energy markets with phenomena taking place at finer spatial and technological scales, such as crop planting at the scale of agro-ecological zones (

Figure 1; 14 geopolitical regions and 151 agro-ecological zones). It was also designed to integrate modeling of higher sectoral or spatial resolution (e.g., crops) with coarser resolution modeling (e.g., global climate). For example, it can link a 50-state representation of the U.S. with the rest of the world disaggregated into 14 geopolitical regions. It can link a global-scale climate model with the building sectors that will form the basis of megacities, and it can be scaled to provide detailed scenarios for a single geopolitical region or aggregated to a broader scale.

GCAM is a Representative Concentration Pathway class model. This means it can be used to simulate scenarios, policies, and emission targets from various sources including the Intergovernmental Panel on Climate Change (IPCC). The model output includes projections of future energy supply and demand and the resulting GHG emissions, radiative forcing and climate effects of 16 GHGs, aerosols, and short-lived species at 0.5x0.5-degree resolution—all contingent upon assumptions about future population, economy, technology, and climate policy. The following sections provide example outputs of GCAM for scenarios focused on building energy demands, food security through crop productions and market analysis, tradeoff scenarios between food and water sectors, and the potential for down-scaling scenarios to a specific megacity region. Data for energy system (including technologies and fuels), water supply and demand, economics, population dynamics, and emissions operate within and between these fields.

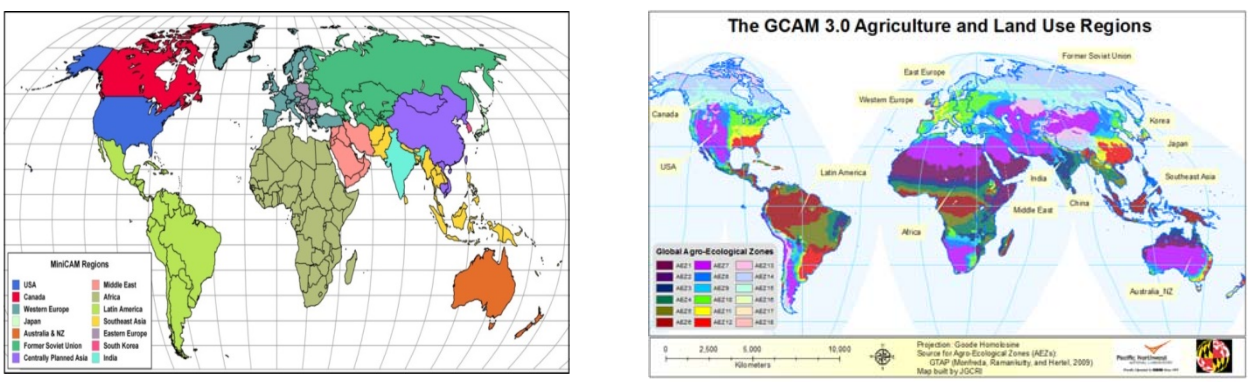

Figure 1. The Global Change Assessment Model (GCAM) utilizes geographic boundaries for a) geopolitical regions that represent 14 major energy and economic regions of the world and b) 151 agro-ecological zones that represent primary climate-based boundaries for crop systems.

Integrated Assessment of Forces Influencing Megacities of the Future

Building Energy Demand out to 2095

GCAM is a technology-rich model. It represents energy sector detail by three end-use sectors (Building, Industry, and Transporation), energy supply, and energy transformation sectors including fossil fuels (oil, natural gas, coal), biomass (traditional and modern), electricity, hydrogen, and synthetic fuels. Scenarios can be developed that hold one set of variables constant in order to test the interdependencies of others. For example, if policy assumptions are applied uniformly across all countries, GCAM can examine how population, migration, and climate change interact to create variable demand on building heating and cooling energy in commercial, industrial, and residential buildings out to 2095. Because all of the driving factors vary spatially, the implications vary regionally.

GCAM was recently used to compare the effect of global climate change, population distribution, and mitigation policy on building energy demand in the U.S. versus China (Zhou et al., 2013). The uncertainty of the impacts of climate change on the heating and cooling requirement was estimated using the number of future heating and cooling degree days (HDD/CDDs) that might occur under two policy scenarios: 1) no-climate policy and 2) a carbon emission policy scenario. The analysis assumed an emission policy was implemented by sufficient member countries to stabilize the atmospheric carbon dioxide (CO_2) concentration at 550 parts per million by volume (ppmv) and included three scenarios of gridded population distribution. The integrated energy technology and earth systems models required three key modeling actions: 1) define the potential future global technological and economic conditions that drive the amount of greenhouse gas input to the atmosphere (e.g., CO_2 concentration pathways); 2) run the global climate models to estimate the HDD/CDDs resulting from this technology and policy mix; and 3) define the demographic and population scenarios that best describe likely shifts in populations including age profiles, urban vs. rural, and migration between climate zones. All three of these steps used input from carefully vetted scenarios emerging from the IPCC and other bodies of work designed to capture known interactions, data, and trends (Nakicenovic et al., 2000; IPCC 2001; Collins et al., 2006; Russell et al., 2000; Gordon et al., 2000; Grübler et al., 2007).

The implications that changing climate and population distribution might have for building energy consumption in the U.S. and China were then explored by using the results of HDD/CDDs as inputs to a detailed, building energy model, nested in GCAM. The results across the modeled changes in climate and population distributions indicate that unabated climate change would cause the building sector's final energy consumption to decrease modestly (6% decrease or less depending on climate models) in both the U.S. and China by the end of the century as decreased heating consumption more than offsets increased cooling using primarily electricity (Figures 2 & 3). At first this may seem like a positive development due to decreased overall energy requirements as a result of climate change. However, national averages do not tell the entire tale relative to megacities. For very large urban areas, climate change combined with urban heat islands will result in an even higher electricity demand for cooling than shown here. In some parts of the world, this is already a critical human health issue in the hot summer months.

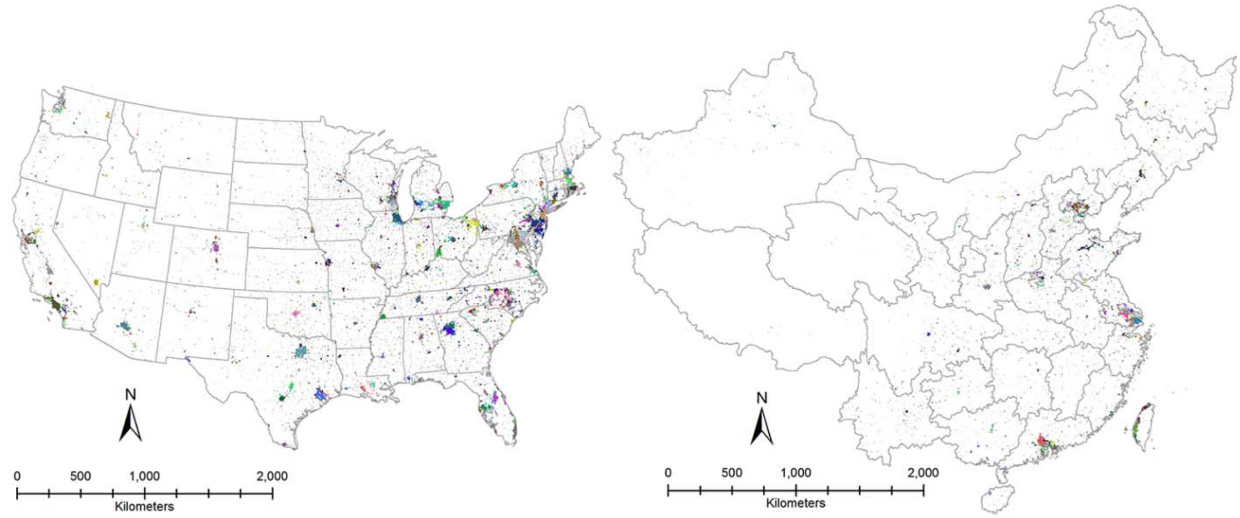

Figure 2. Potential U.S. and China urban clusters by 2095 derived by statistical data projections from baseline nighttime lights imagery from the Defense Meteorological Satellite Program's Operational Linescan System; (Zhou et al., 2014). These data help make building energy demand data from other sources spatially explicit.

In this scenario, climate change generally results in a larger increase of cooling energy use in China than in the U.S., while the decrease in heating energy use is about the same in both countries. Depending on the climate models, the U.S. has a 20–35% increase in cooling energy use and 9–20% savings in heating energy use, whereas China has a 37–41% increase in cooling energy use and 12–19% savings in heating energy use. Although the HDDs and CDDs change roughly at the same rates in the two countries, the asymmetric energy response results from far less ubiquitous cooling service in China than in the U.S. When increased CDDs induced by the climate change are combined with China's rapid income growth, cooling service and associated cooling energy use will grow faster in China than in the U.S. during the 21st century. With abated emissions (i.e., the 550-ppmv scenario), however, the trends in heating and cooling energy uses are not noticeably different between the two countries as the magnitude of the impacts become relatively small in both countries.

When the impacts are downscaled to a region, megacities are projected to be warmer in the future. This would drive an across-the-board increase in cooling requirements that directly translates to increases in demand for electricity. For megacities this will put considerably more pressure on the electrical grid and electrical power-generation infrastructure to maintain healthy conditions. This need for more electrical power generation also has ramifications for other parts of the integrated system such as water resources for power plant cooling and material for electrical transmission.

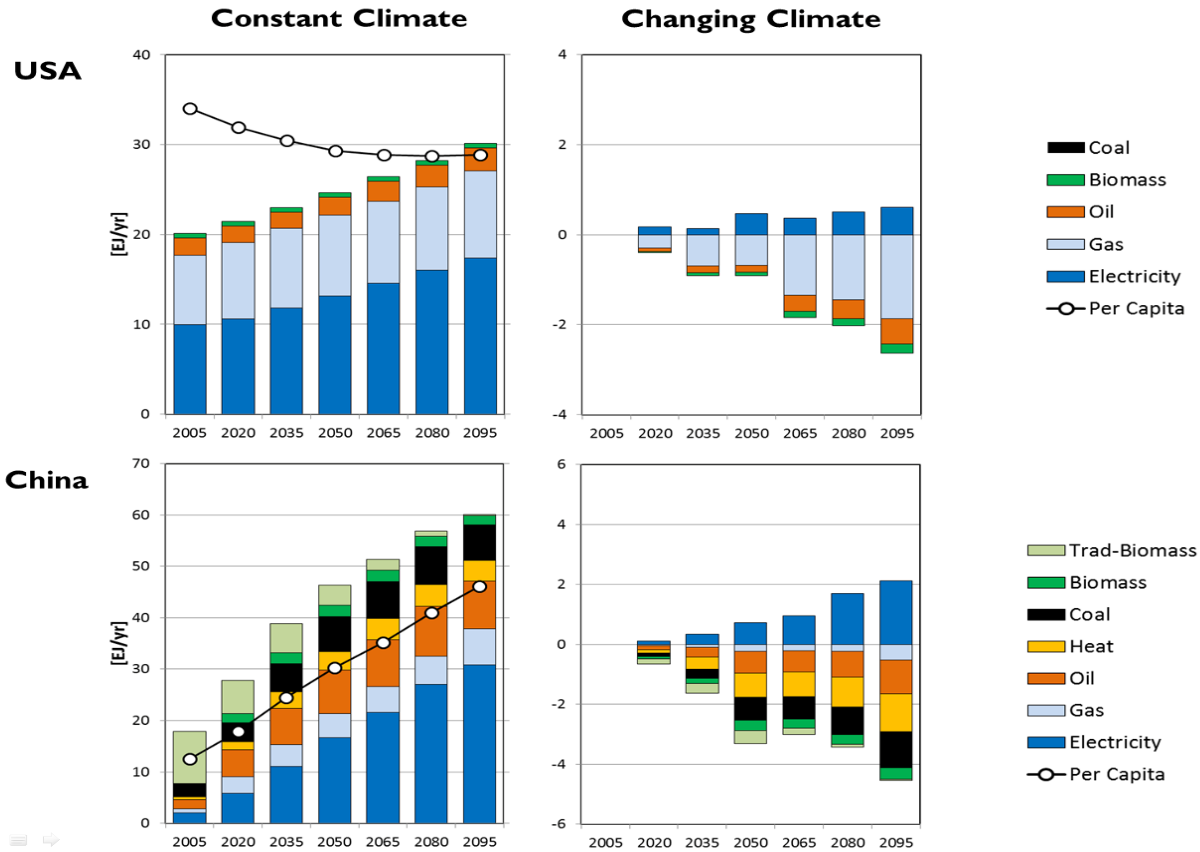

Figure 3. Absolute and per capita building energy demand out to 2095 by fuel in the U.S. and China (Source Zhou, 2013) highlighting a need for more cooling in the building sector resulting in an added demand for electricity in megacities. Changing climate is represented by the SRES B1 Scenario, or and constrains 550 ppmv CO2 in the atmosphere to 550 ppmv by 2100. Note that for both simulations, coal is not utilized for the US, but remains a significant fuel for China. Also note, that for constant climate, by 2035, the trend for energy demand per capita in the US begins to level out, whereas, China's demand continues to increase. On the right, changes in fuel demand under changing climate are calculated as the difference between the simulated year minus the demand in 2005. In both cases, megacities in the future will be evermore reliant on the electric infrastructure.

In a U.S. centric scenario, the GCAM analysis was downscaled to the state level to further resolve impacts by sector and identify potential urban clusters or megacities showing higher rates of energy use. This approach provides higher-resolution demographic and energy-use data within the U.S. computed in the context of global climate, energy, and socioeconomic forcing factors. The state-level assessment reveals a situation by 2095, where despite lower overall energy demand with changing climate, demand for electricity went up (Figure 4).

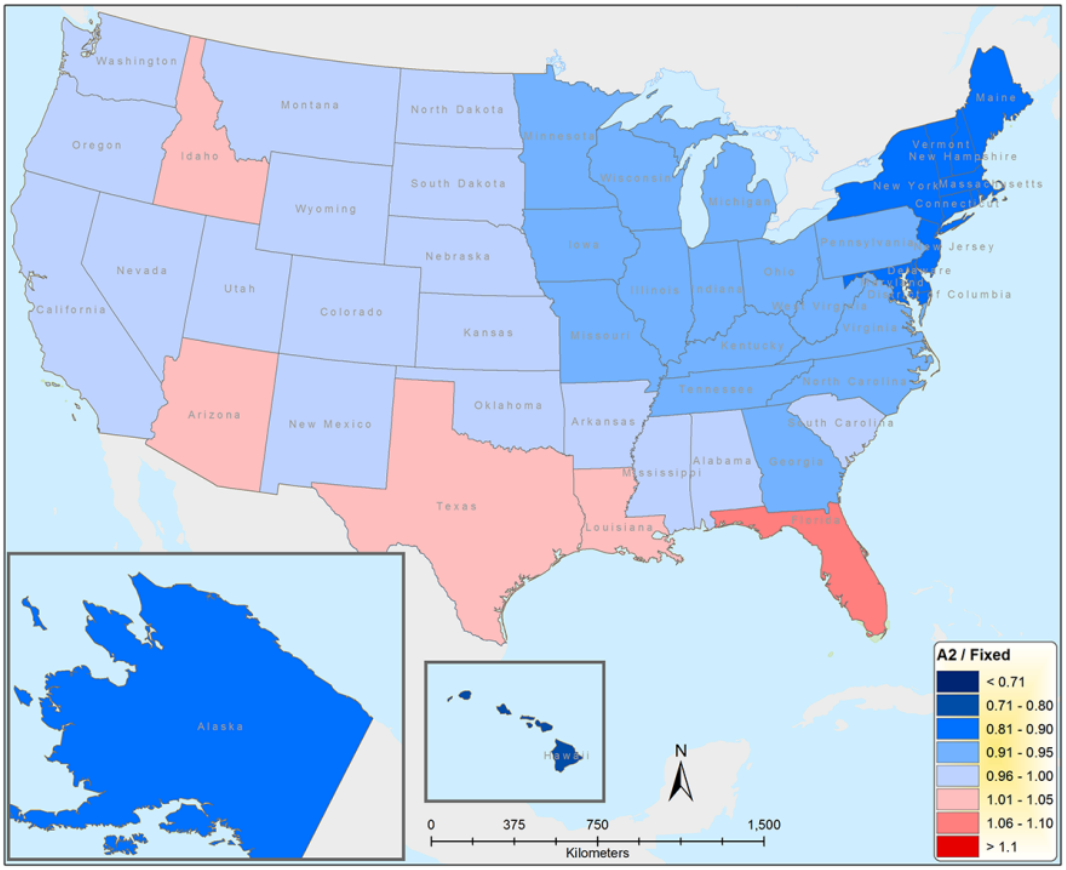

Figure 4: Figure 4. Cumulative building energy use in the 21st century with consideration of climate feedback in the IPCC A2 Marker Scenario relative to that use without climate feedback (fixed) (Zhou et al., 2014). Some States gain by climate change with reduce

Food Security: Interdependence of Global Food Production and the Energy System

For most of human history a majority of populations lived in rural settings engaged in agricultural pursuits. But during the 20th and 21st centuries, the share of populations living in urban environments has climbed steadily such that the present share of rural populations has declined to approximately 47% in 2012 (e.g.. 66% in 1960). Concomitantly, the share of global gross domestic products (GDP) originating from agricultural activities has declined precipitously.

Research using GCAM can explore the interactions of the agricultural system and the energy system within the context of different future policy options. Such research has pointed to the importance of future land availability for agriculture in determining future food prices, which has implications for food security. In the current GCAM calculation, the demand for food is inelastic; that is, enough food must be produced to feed everyone on the planet. However, as competition for land for urbanization, bioenergy crop production, or carbon sequestration through afforestation increases, the price of food rises and the balance of food consumed shifts away from animal products, which are more land intensive to produce.

A recent study, Calvin et al. (2013a) conducted scenarios in GCAM to explore the implications of climate change mitigation decisions on food production to evaluate potential unintended consequences from policy decisions. They found that global crop prices are sensitive to climate mitigation policies; for example, wheat prices are likely to increase with climate change, even in the absence of any concerted policy efforts to reduce GHG emissions or increase bioenergy usage (Figure 5 –Left).

When climate change mitigation policies that place additional economic value on land through a carbon tax that values bioenergy crops or carbon storage in forests are assumed, the prices of agricultural commodities are also affected. Using GCAM, Calvin et al. (2013b in press) found that the type of policy or regulation imposed on terrestrial carbon and forest resources can have a large effect on food prices. Comprehensive policies, such as putting an economic value on all terrestrial carbon emissions, are most effective at reducing the cost of climate change mitigation efforts, but also result in a threefold increase in the price of wheat (Figure 5 right - universal carbon tax (UCT) and 99% land scenario). Alternate policies that preserve forest area or specifically regulate bioenergy can keep food prices low, but result in higher mitigation costs.

Increases in global food prices from both direct climate change impacts and indirect policy decisions related to climate change mitigation and adaptation could exacerbate regional and local food security issues and conflicts. This is especially true as urban dwellers are primarily consumers of agricultural products and not producers. Future work under way on this topic is explicitly exploring regional self-sufficiency in agricultural products and the implications of potential future water scarcity for agricultural production and costs.

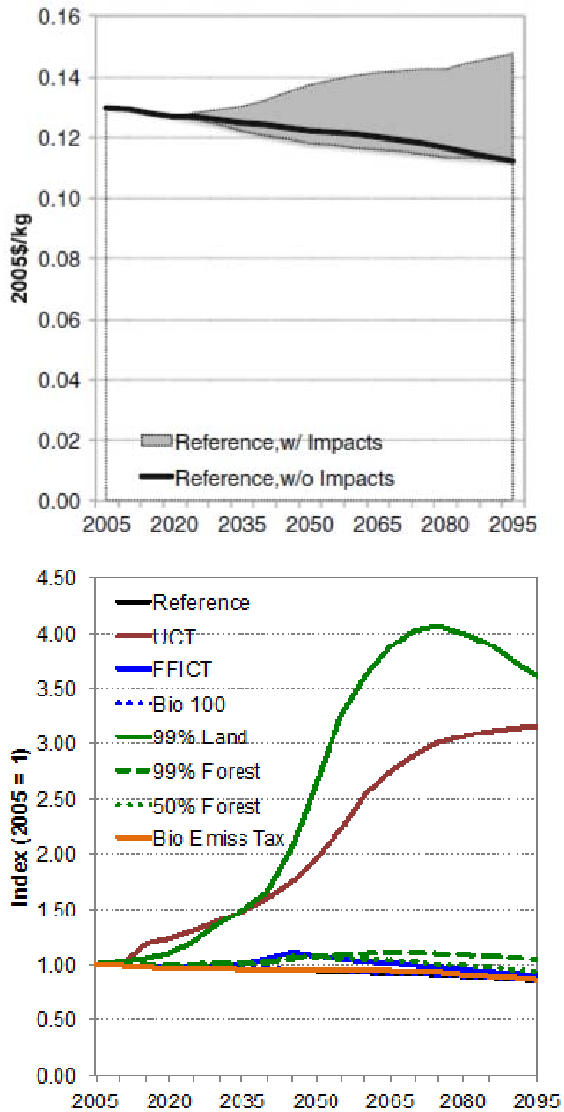

Figure 5: Figure 5. (Left) Global wheat price projected in GCAM for a suite of scenarios representing no major climate policies and no climate impacts (solid line) or the range of climate change impacts projected in the IPCC Fourth Assessment Report (grey area)

Future Water Demand: Agriculture versus Energy

Estimation of growth in total water demand relies on our understanding of the underlying social, economic, and environmental drivers of changes in sectoral water demands. A sufficient, secure water supply is essential for meeting basic human needs and for the functioning of many sectors of the economy, making an understanding of future water demands crucial for policy makers to address the water scarcity challenge for the generations to come. In a recent study (Hejazi et al., 2013), GCAM was used to assess future water demands representing six socioeconomic scenarios through the end of the century. Within the six storylines, GCAM identified two broad descriptors: either progress develops ahead of or copes with rising populations, or the objective described in the United Nations Millennium Development

Goals (MDGs) is not achieved and the proportion and number of extremely poor increases. For each group, we explored the implications of these sets of futures and their associated trends in domestic governance, international relations, population patterns, and environmental conditions. The goal was to examine the demands on water and other resources, as well as the human, financial, and environmental capacity to meet them.

The modeling framework explicitly tracks future water demands for the agricultural (irrigation and livestock), energy (electricity generation, primary energy production and processing), industrial (manufacturing and mining), and municipal sectors (Figure 6). The energy, industrial, and municipal sectors are represented in 14 geopolitical regions, and the agricultural sector is further disaggregated into as many as 18 agro-ecological zones within each region.

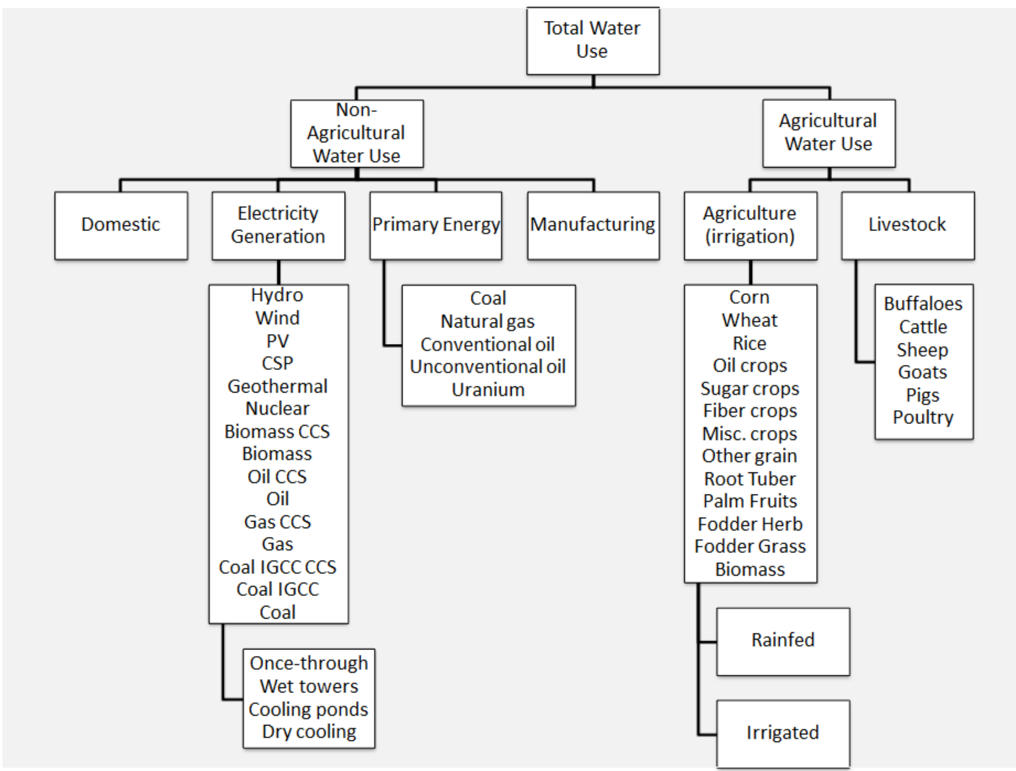

Figure 6: Figure 6. Representation of all components of the water-demand sectors in GCAM.

The results of these scenarios all showed increases in global water withdrawals with 3710 km^3 per year in 2005, 6195–8690 km^3 per year in 2050, and 4869–12,693 km^3 per year in 2095. Comparing the projected total regional water withdrawals to the historical supply of renewable freshwater, the Middle East exhibits the highest levels of water scarcity throughout the century, followed by India (Figure 7) This is a particularly salient scenario for Karachi, Pakistan. Pakistan has a prominent agricultural sector that makes up 23 % of the GDP and 44 % of the labor force, but faces sharp tradeoffs in water allocation geographically and between farming and power generation. The flow of the Indus River, which irrigates much of Pakistan, is likely to decrease as the Karakoram Glacier shrinks. Rising ambient temperatures will also affect growing cycles while increased precipitation variability will lead to droughts in some regions and floods in others. From a security perspective, these vulnerabilities could interact with the internal protests that are already occurring in response to repeated power outages. In contrast, water scarcity improves in some regions with large base-year electric sector withdrawals, such as those in the U.S. and Canada, due to capital stock turnover and the almost complete phase-out of once-through flow cooling systems.

The GCAM framework demonstrates that 1) freshwater availability may be insufficient to meet all future water demands in some regions such as the Middle East and India; 2) many regions can be expected to increase reliance on non-renewable groundwater, water reuse, and desalinated water, but they also highlight an important role for development of water conservation technologies and practices particularly in megacities of developing countries; and 3) tradeoff scenarios between agricultural and energy needs for water may drive instability in already sensitive countries.

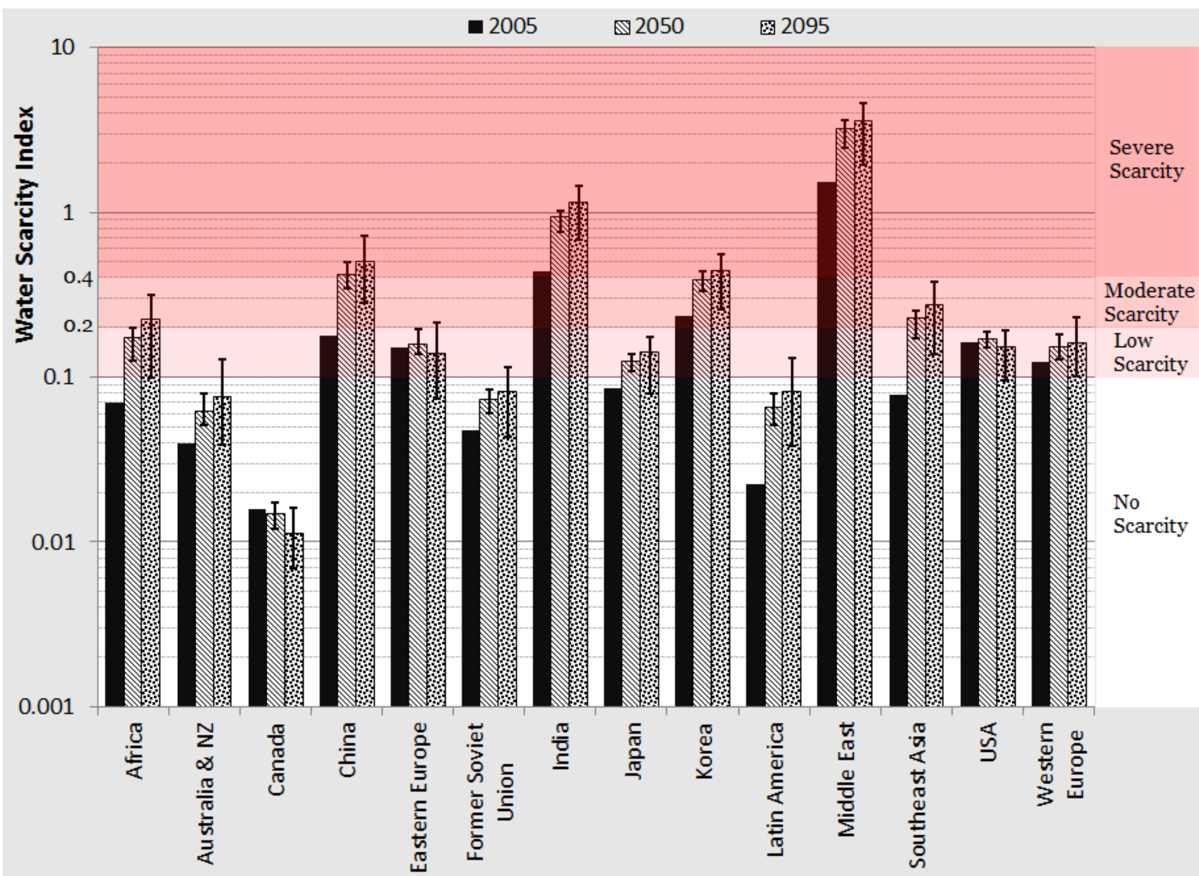

Figure 7: Figure 7. Water scarcity index (WSI) in years 2005, 2050, and 2095 in the 14 GCAM regions due to changing water demands. Total water supply (renewable water + desalinated water) is assumed to be fixed to 2005 levels to capture the effect of demand pro

Downscaling Integrated Assessment Models – Regional Expressions of Global Forces

Global forces, whether driven by human systems (migration, trade, etc.) or the physical environment, affect regional and local systems. For instance, changes in the global climate system, such as the frequency and magnitude of El Nino events or monsoon seasons, are expressed at regional scales through droughts, floods, or extreme temperatures and can have destabilizing impacts on societies. Such changes are not well captured by global models. Global models, however, provide boundary conditions, or global forcings when downscaling to regional models. In the climate system, regional models are either downscaled through statistical representations or based on physical representations of the climate system that are relevant for regional analyses, such as accounting for topographic features, management practices such as forestry or agriculture, and hydrologic systems. At this scale, changes in climate extremes may present larger challenges for climate mitigation and adaptation than changes in mean climate because megacities are vulnerable to extreme events (e.g. Super Storm Sandy). Hence, regional expressions of global forcings can be considered through integrated frameworks that account for regional climate-related drivers of energy production and socioeconomic processes (e.g., Hibbard and Janetos, 2013). An example of this framework is the Platform for Regional Integrated Modeling and Analysis (PRIMA) which allows simulations of extreme climatic events and their impacts on and interactions between energy demand, energy infrastructure, water resources, and crop productions.

Accompanying the changes in the global energy balance are changes in atmospheric moisture, which scales with temperature, and large-scale atmospheric circulation such as shifts in the storm tracks. Overall, climate models have projected an intensification of the water cycle with more frequent and intense extremes including both floods and droughts in the future (e.g., Held and Soden, 2006). For megacities, this generally means more frequent flooding, particularly since many megacities are located on the perimeters of continental margins, coastal zones, or rivers. Modeling tools such as PRIMA are required to evaluate the potential frequency and magnitude of flooding in megacities. For example, coastal cities and megacities may be vulnerable to synergistic coupling of sea-level rise, increased storm frequency, and increased storm intensity. Regions such as the U.S. Gulf Coast are perfect examples of the vulnerability of energy systems in urban centers where the environmental system no longer provides adequate protection from storm surge caused by subsidence of the land related to resource extraction or a complete loss of the coastal structure (Figure 8).

Inundation of coastal systems may result in potential migration patterns, which may cause conflict in already vulnerable areas outside the U.S. For example, Bangladesh is particularly vulnerable to climate change as the eighth most populous country in the world and its capital, Dhaka, is one of the world's fastest growing megacities. Along with governance challenges, much of Bangladesh's land area is less than one meter above sea level, and the IPCC reports that the country will lose 17–20% of its land mass by 2050. This would likely displace more than 20 million Bengalis. Many would try to relocate internally, but international tensions could rise if many seek refuge in India. Bangladesh's larger neighbor has already erected a fence and border guards will use lethal force against those who come too close. Regionally downscaled models could further evaluate the vulnerability and resiliency of the human and earth systems to both current weather events and long-range climate changes.

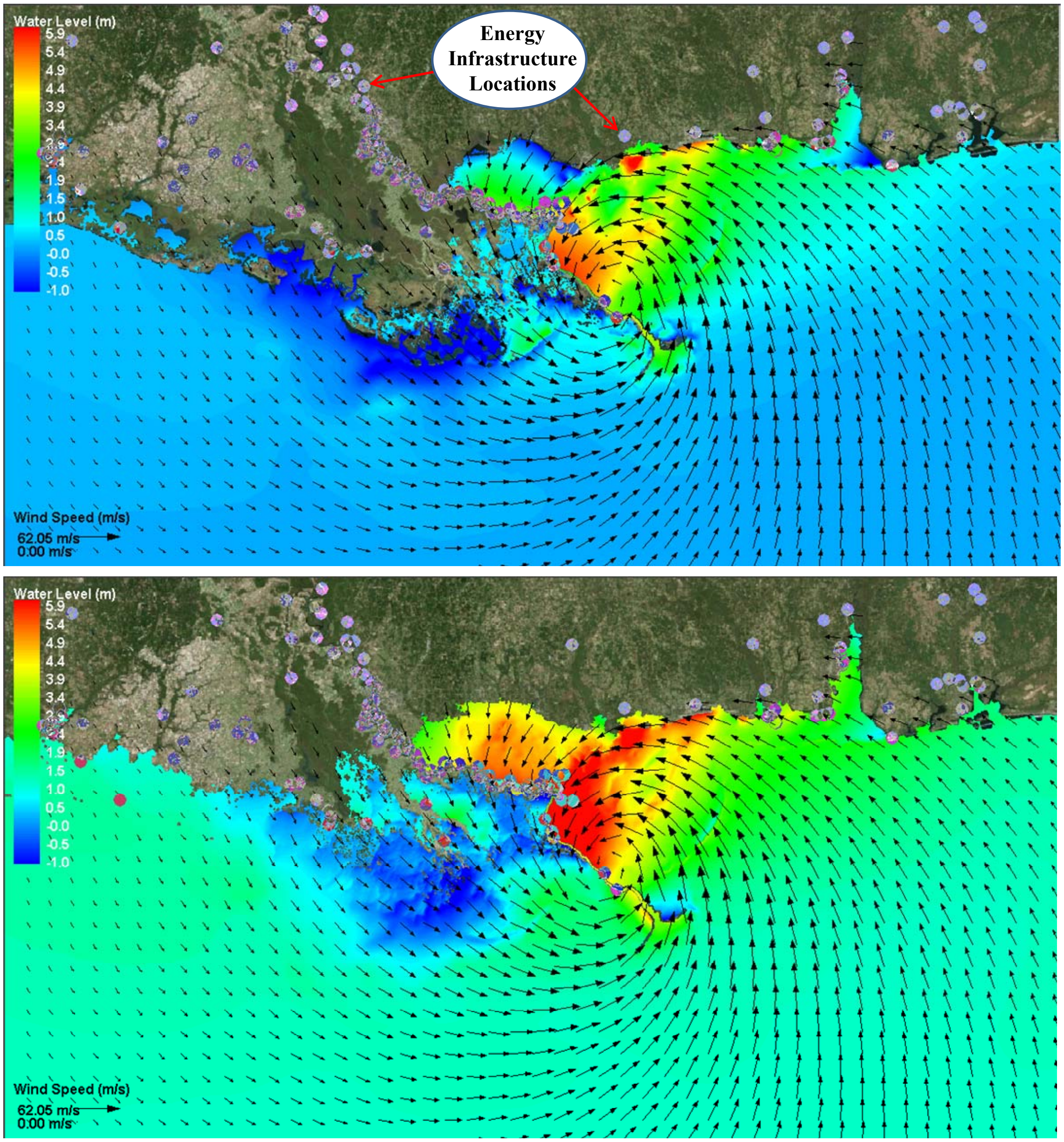

Figure 8: Figure 8. Simulated near-surface winds (arrows) and storm surge (color bar) induced by a Katrina-like hurricane in the Gulf of Mexico for current conditions (top panel) and with one meter of sea-level rise and regionally-varying land subsidence of 0-2.

Conclusions

Who will the “winners” and “losers” be in a changing world? Climate change is considered a threat multiplier and the defense community recognizes the need to consider the physical environment when evaluating the fragility of peace. The large populations and interdependent nature of megacities highlight the criticality of focusing crisis mitigation actions on economic, diplomatic, and ecological components, not just military solutions. The vulnerability of megacities to climate change impacts is a function of the direct effects of a climate event, the second- or third-order effects driven by the dependencies on globalized systems, and unintended consequences of policies. Therefore, the security risks for megacities cannot be predicted without also bringing in multiple interacting factors that include energy, policy, economy, and demographic changes as significant drivers. By considering these drivers in a single model, IA approaches allow for the interrogation of how these interacting factors may create inequities in impacts and define "winners" and "losers" in more sophisticated ways. Understanding how these inequities will manifest themselves, which could range from regions and countries to economic sectors or age cohorts within or across countries, will help identify the potential threats that might arise from them.

IA models such as GCAM show how both climate and policy choices can interact to change the energy paradigm in megacities and potentially generate economic stresses due to competing demands for food and water resources. Even if projections 50 or 100 years into the future seem extreme, these timescales are useful for establishing the trends that are in play now and in the immediate future (see Malone and Moss in this issue). For example, it is likely that urban heat islands combined with (or even in the absence of) climate change will result in overall warmer temperatures in megacities in both the near- and long-term futures. This will put considerably more pressure on the electrical grid and electrical power-generation infrastructure to maintain healthy conditions in megacities and failures will be felt even more keenly by urban populations. These IA models show how migration of populations to megacities and away from agricultural practices coupled with the need to enact climate change mitigation strategies (e.g., carbon taxes, increased bioenergy, etc.) have a direct impact on future food prices. Energy policies that exacerbate the competition for land (for bioenergy crop production, or carbon sequestration through afforestation) can greatly increase the price of food (e.g., wheat prices) creating inequities between producers and the urban consumers. In the future (as now), the Middle East followed by India will experience the highest levels of water scarcity. These regions can be expected to increase reliance on non-renewable groundwater, water reuse, and desalinated water and face tradeoff decisions between water needed for agricultural and energy needs. In contrast, water scarcity actually diminishes in the U.S. and Canada as a result of capital stock turnover and the almost complete phase-out of once-through flow cooling energy production systems. Having the ability to understand how these factors trade or amplify in an IA modeling domain allows for projections about who "wins" or who "loses" in a changing world.

Preserving Phase 0 conditions in megacities will require preemptive actions across multiple sectors in an interdisciplinary approach to prevent reaching critical tipping points that could rapidly drive a high-density population into conflict. However, existing modeling paradigms and their inherent uncertainties do not necessarily map cleanly onto policy and human decision making processes. IA models, such as GCAM depend on well-conceived and vetted scenarios that explicitly account for climate, climate change mitigation policies, and likely socio-economic factors at greater spatial resolutions and shorter time steps. The IC can contribute to the development of this new IA capability. Planning for Phase 0 operations begins with a dialogue across these communities to map out a clear plan to harness the rich assets and potential to leverage existing capabilities. Development of a spatially explicit representation of vulnerability and threats to megacities coupled with an IA approach now and into the near future will benefit society, enhance national security and provide leadership opportunities for international consortia.

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Chapter Three, Understanding Megacities-RSI – Dhaka's Design as an Expression of Culture & Politics

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Abstract

Dhaka is not a single entity; rather it is a conglomeration of populations whose histories and contemporary interests form around communities, called *mahallas*. By focusing on the *mahalla* as the building block of Dhaka society, it is possible to more accurately capture Indicators and Warnings (I&W) of instability. This chapter explains why the *mahalla* is important in Bangladeshi ontology and how it applies to the RSI-Dhaka initiative. It then describes the basis of social tension in Dhaka forming around political Islam in modern Bangladeshi politics despite a secular socialist independence movement and Sufi Muslim past. The chapter concludes by assessing the consequences of Dhaka's evolution as an unplanned megacity based upon the propensity for natural disaster and social tension, which are now exacerbated by the rise of political Islam.

Keywords

Dhaka, *mahalla*, ontology, RSI, political Islam, *hartal*

Introduction

While Dhaka's layout might appear to defy logic to foreigners (Mowla, 1997, p. 270), understanding Bangladeshi ontology reveals the organizing principles of the neighborhoods, and, therefore, the substance of politics, values, and the needs of each ward. Indigenous Bangladeshi culture is rooted in community and social space based principally on agricultural production. Even a megacity like Dhaka continues in its basic form to evince these values despite rapid, unplanned growth. The content of *mahalla* socio-political space is thus likely to be characterized by a fairly cohesive set of networks and interests and can serve as the analytical baseline for the M-RSI Dhaka initiative.

Instability in Dhaka is likely to arise from two main sources, natural disaster befalling shanty communities and political skirmishes between leftist and Islamist political parties. Historic Dhaka follows the *mahalla* design and consists of families with long histories and similar socio-political interests. Recently constructed Dhaka will likely reflect modern city design with liberal and Islamist residents, or be the result of rapid, unplanned growth in areas prone to flooding by recent rural migrants. Since the *mahalla* is the ontological foundation of both historic Dhaka and rural populations, it provides a good I&W baseline to measure social and political instability.

Mapping out *mahallas* can be undertaken by two complementary practices. First, geospatial analysis of Dhaka can identify traditional from modern stretches of development and the likely boundaries between *mahallas*. Second, ground-level research can verify the boundaries and further investigate the values, attitudes, and interests of each *mahalla*. This combined effort should reveal in relatively short order and with minimal expense the areas of Dhaka that most likely threaten stability and the content of the ontology and political reality that could serve as the threat vectors.

This chapter explains why the *mahalla* is important in Bangladeshi ontology and how it applies to the RSI-Dhaka initiative. It then describes the basis of social tension in Dhaka forming around political Islam in modern Bangladeshi politics despite a secular socialist independence movement and Sufi Muslim past. The chapter concludes by assessing the consequences of Dhaka's evolution as an unplanned megacity based upon the propensity for natural disaster and social tension, which are now exacerbated by the rise of political Islam.

Neighborhoods and Community Space in the Bangladeshi Ontology

The basic building block of Bangladeshi villages is the mahalla (Mowla, 1997, p. 259), and even Dhaka as a megacity still exhibits most of the ontological underpinnings of Bangladeshi culture. Each mahalla is a series of circular households (ghar) combined into larger units. A family line generally cluster ghars into homesteads (bari), and the homesteads combine to become family lands (paribar). Multiple paribar form neighborhoods (para), and multiple neighborhoods form villages (gram) (Mowla, 1997, p. 264).

Being rooted in community relationships, Bangladeshi ontology leads every level of community development to orient around social space. Ghars form a circle around central squares as do bari, paribar, para, and ultimately grams. Additionally, Bangladeshi ontology maintains the difference between men and women's social space. Each ghar has a public space immediately adjacent to the public center and a privacy wall separating the interior space of the family life from the community. The formal, public space of the ghar is reserved for men, and women inhabit the interior courtyard. Bazaars (hat) serve each gram, though they are typically placed along main streets. Ghars are found behind the hats (Mowla, 1997, p. 264).

This basic mahalla form has been considerably compressed in the urban environment, even in the older quarters. Urban ghars typically consist of a semi-circular home with a central courtyard reserved as social space. Narrow alleys (gali) separate ghars to form bari. Women and children have traditionally been allowed to view this space as accessible for socialization. Broader streets (mahalla) connect bari together into paribar, with corners (morh) becoming important social space mainly for men and adolescent males. It is at this level that urban community space is established and the character of the socio-political content formed. Formalized social space (mosques, theaters, etc.) are called chouks and are important venues for interaction among young males. Hats, or markets, serve the grams and many are now found forming long stretches of shops along main roads and are the place for adults to conduct business (Mowla, 1997, p. 265).

From the outside looking in, the mahalla is, thus, a series of inward facing social spaces with a larger community that gets progressively more discreet and family oriented. From the inside looking out, the mahalla is a kinship, mutual support network that grows while balancing the need for privacy and ever larger communities of relationships. Galis, alleyways (uthan), morh, and chouks all rely upon Bangladeshi logics of appropriateness that stress outdoor, communal interaction. Mowla explains,

> On a city scale, the bazar appears to be a long street lined with shops, but actually is a sequence of bazars passing through different mahallas. The continuity is emphasized because of being specifically built up in terms of the shop fronts…Thus a single pattern…gives rise to two different built forms and the indigenous city appears to consist of linear bazars and circular mahallas. It appears that other informal settlements have a similar morphological pattern that was detected in the pre-planning indigenous areas. (1997, p. 267)

Modern stretches of Dhaka are more likely to resemble contemporary, automobile based planning, but even unplanned shanty communities demonstrate much of the traditional village characteristics (Mowla, 1997, p. 269). Mowla continues,

> Besides the core pattern of mahalla and bazar, a careful observer can also see a logical arrangement of land uses in indigenous Dhaka. The network of streets and alley ways or galis evolved as a type of built-in system of traffic control and informal but effective zoning plan (Mowla, 1990, p.30). The spaces between the buildings are vibrant and provide many closed and short vistas, which make streets and galis comfortable, satisfying and secure to walk through. The overall sequence shows a unity of pattern with buildings and spaces tending to increase in importance as a public area/building is approached. This visual patterning, as Scargill (1979, p.193) prefers to call it, accounts for the ease with which the residents find their way about in what, to a stranger, is a labyrinth of galis. (1997, pp. 269-270)

Indigenous Dhaka society relied on local councils of five respected men (punchayet) to govern the use of mahalla territory (Mowla, 1997, p. 262). In indigenous Bangladeshi culture, any individual can alter a public space so long as neither the punchayet nor another member of the mahalla objects (Mowla, 1997, p. 273). In this way, neighborhoods police themselves and maintain harmony based on local perceptions and needs. It is unclear the degree to which the punchayet system remains effective, but it could serve as an important system of checks and balances as Dhaka experiences rapid expansion.

Bangladeshi Politics and the Influence of Islam

Dhaka's main political source of instability is now a function of the entrenchment of political Islam in government and political party coalitions. Over the last three decades, the re-introduction of Islamism into the government and political sphere has led to tensions in the city, which are likely to be represented by concentrations or clusters of like-minded people in distinct neighborhoods. The fault lines can be mapped and monitored over time to identify drivers of instability using the mahalla as the unit of analysis.

Although Bangladesh is in part comprised of the world's third largest Muslim population, the population itself is historically suspicious of political Islam. The population's conversion to Islam was accomplished through Sufi orders that allowed syncretic practices and tolerance for religious difference (Riyaja, 2003, p. 302 & 304; Ahmed, 2009; Ahmed, 2010). Inherent to the ontology of most Bangladeshis, then, is a basic acceptance of others regardless of religious affiliation.

The Bangladeshi independence movement leveraged the indigenous ontology that expressed cultural and linguistic respect for and inclusion of all religious groups whether Muslim, Christian, Hindu, or other (Anisuzzaman, 2008). The first government, represented most powerfully through the Awami League (AL), espoused secular socialism and the institutions of state sought to create a sense of inclusion along non-religious lines. The first constitution even banned the use of religion in politics (Riyaja, 2003, pp. 301-302). Secularism in the Bangladeshi government context was defined as neutrality of the state toward religion, meaning that it acts as an arbiter guaranteeing equal access, not a non-religious polity (Riyaja, 2003, p. 303).

Bangladeshis also retain an active memory of the millions killed by the Pakistani military and indigenous Islamist groups in the war for independence in 1971. The Pakistani military attempted to use adherence to political Islam as a basis of national unification. Riyaja explains, "The exploitation of Islam by the Pakistani colonial rulers to legitimize the perpetuation of the colonial rule and the excesses committed by the Pakistani Army and collaborating Islamic parties 'to save the integrity of Islamic Pakistan' created bitter resentment among the people against the use of religion in politics" (2003, p. 309).

A crisis of legitimacy came early for Awami League, due to an inherent limitation in its drive to create a national identity. As a cultural and linguistic movement, the Bangladeshi independence leaders established a framework setting the stage to deny ethnic and tribal minorities a place since the nation was formed for Bengalis (Riyaja, 2003, p. 309). There are, consequently, minority groups whose ontologies are ones of exclusion or marginalization, such as Urdu speakers left as refugees after 1971 (Kelley, 2010) and the hill tribes located predominantly in the eastern part of the country (Riyaja, 2003, p. 309). Under these circumstances, integration through religious identity is often seen as a means of gaining access to politics and opportunity.

Socialism, nationalism, and democracy comprised the original platform of Awami League, but radical leftist members and peasant parties split from AL in pursuit of a pure scientific socialist government and freedom from Soviet Union and Indian government influence (Riyaja, 2003, p. 307; Rashiduzzaman, 1994, pp. 976-979). With the assassination of the secular president in 1975 during a military coup d'état and after two years of counter coups, a military dictatorship under GEN Ziaur Rahman was formed (Riyaja, 2003, p. 310).

Political Islam re-entered Bangladeshi society in 1977. GEN Rahman did not participate in the 1975 coup, but he faced a challenge of fomenting a new national identity upon taking control. His political legitimacy was questionable, and he needed a unifying identity construct other than the now-discredited class discourse. He chose nationalism against India, the religious identity of the majority, and the role of the military in national independence (Riyaja, 2003, p. 310). Rahman eliminated references to secularism in the constitution and inserted language trusting the government to the will of Allah. Nationalism was from this point on intertwined with Islam (Riyaja, 2003, p. 303).

In 1978 Rahman's government established state support for madrassas and the introduction of Islamic curriculum in primary and secondary schools, creating the conditions, especially with Saudi assistance, for a longer term ontological transformation of Bangladeshi culture to include a stronger Islamist component (Riyaja, 2003, p. 311). Though the state began the process of elevating religious Islamic identity in Bangladeshi society, the process did not eliminate the basic tolerance of most Muslims. In 1979, the two major Islamist parties garnered just 20 parliamentary seats (8% of the popular vote) in that year's election (Riyaja, 2003, p. 311).

GEN Ershad, Rahman's successor, also used political Islam as the basis of his legitimization. He formed alliances with Muslim religious leaders and in 1988 made Islam the state religion. The secular opposition was unable to effectively resist his efforts to politicize religion or topple his military rule until 1991 (Riyaja, 2003, pp. 301-302 & 311-312). The identity effects of nearly fifteen years of rule through a military-religious alliance caused an increase in the number of self-identifying Islamists and a significant rise in the importance of Islamic morality in even historically secular parties' discourse.

Traditional centrist parties in early 1990s faced an environment where Islam was partly constitutive of the national consciousness, so most adopted a political face of supporting good Islamic virtue (Riyaja, 2003, pp. 312-313). From 1991 on, centrist parties felt compelled to form parliamentary political alliances with Islamist parties, thus elevating their status. Jaamat-i-Islami's ability to attract votes increased alone from 750,000 in 1979 to 4.1 million or more in 1991 (Riyaja, 2003, pp. 314-315).

In contemporary Bangladeshi parliamentary politics, Islamist parties are small, but they enjoy significant influence. The two major parties, Awami League (center-left coalition) and Bangladesh National Party (BNP) (formed by GEN Rahman as a center-right coalition) (Hossain, 2000, p. 512), rely on the Islamist parties to fill out their coalitions, which elevates their influence in national politics (Riyaja, 2003, p. 316; Rashiduzzaman, 1994, p. 984). The Islamist parties competing for the religious constituency include Jaamat-i-Islami, Islami Oikya Jote, Parliament), the Islamic Constitution Movement, Khilafat Majlish, National Musalli Committee, Ahl-e-Hadith, Ulema Committee, Islamic Chatra Sena, Jamiatul Modarassin, Nezami-i-Islam, and the Muslim League (Riyaja, 2003, p. 301; Rashiduzzaman, 1994, p. 982).

In sum, Bangladeshi culture remains overwhelmingly Sufi Muslim and largely tolerant of other religions, but a well-organized, motivated, and politically empowered Islamist core of parties have the ability to shape public discourse and politics. Centrist AL and BNP each attract approximately 35% of the vote for a total of 70%, while the main Islamist parties generate only 20% of the popular vote (Hossain, 2000, p. 514).

Political instability in Dhaka is in part a result of this centrist political distribution because AL and BNP engage in hartal[1] politics, or the politics of hyperbole and absolutism. Alliances are generally made for short-term power considerations, while discourse tends to emphasize differences and incite the passions of the people (Hossain, 2000, pp. 516-517 & 521-522).

It is not uncommon for Dhaka to be paralyzed by large demonstrations or for political violence to occur based on hartal agitation. Monitoring narratives and discourse is particular mahallas can provide indications of the intensity of tension in Dhaka, which can then inform hypotheses about the types of sparks that might lead to actual violence and instability. Mapping out the support for each party and assessing the content of contemporary discourse by mahalla could provide a good foundation for the RSI-Dhaka effort.

Dhaka as an Expression of Community, Urban Sprawl, and *Hartal*: The Politics of Unplanned Growth

Dhaka's stability as a megacity is a function of both natural disaster and politics. Due to its rapid growth, location in flood and seismic zones, and hartal politics, Dhaka has a number of natural tensions that could lead to instability. Identifying the substance of tensions and understanding their historical context will lead to better I&W of potential sources of instability.

Dhaka's location in between four rivers made it ideal as a point of communication and crop production, and its highest elevations, reaching approximately fourteen meters were settled first due to persistent flooding (Dewan, Yamaguchi, & Rahman, 2012, p. 317). Historic Dhaka can be found in the upper elevations with newer, especially informal, shantytowns being constructed in the flood plains astride the rivers (Figure 2) (Rashid, Hunt, & Haider, 2007, p. 96; Dewan, Yamaguchi, & Rahman, 2012, p. 327). Figure 3 illustrates the surface usage changes between 1975 and 2005. Dense urban growth (orange) progressively ex-

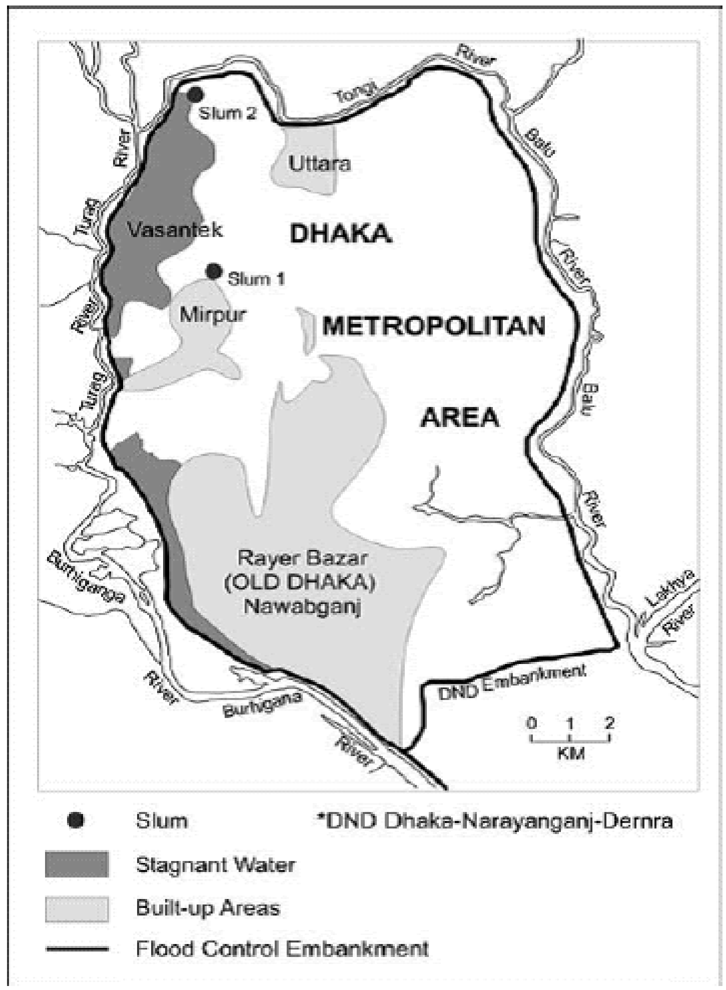

Fig. 1 Location of Slum 1 (adjacent to Mirpur) and Slum 2 (adjacent to Vasantek) in Dhaka Metropolitan Area, Bangaladesh

Figure 9: Figure 9: Location of Slums in Dhaka, Bangladesh

[1] See http://en.wikipedia.org/wiki/Hartal for a full description of Hartal or Hortal.

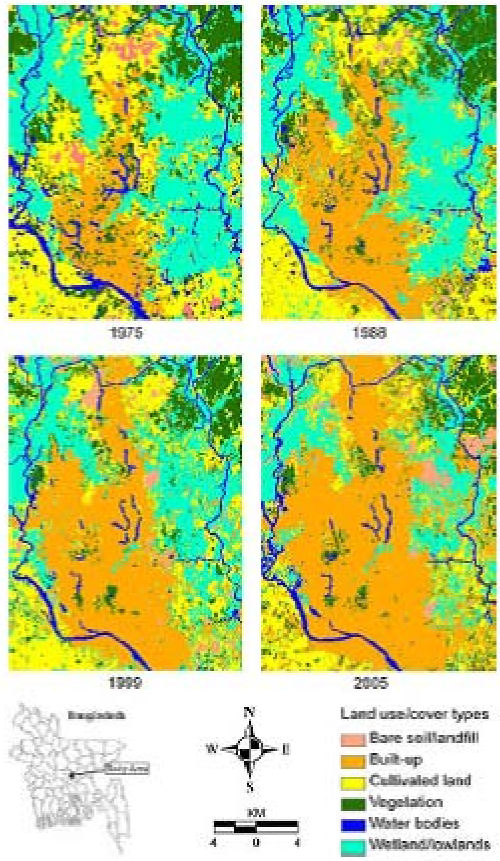

Fig. 2 Land use/cover changes in Dhaka Metropolitan from 1975 to 2005

Figure 10: Land Use/Cover Changes in Dhaka Metropolitan from 1975 to 2005

pands over cultivated land at lower levels (yellow), leading by 2005 to encroachment on areas extremely susceptible to flooding (aqua).1

Dhaka residents' identities and interests depend heavily on their origins and current living locations. Residents living in the upper elevations have access to historic wells or modern water and transportation infrastructure. Limitations on economic opportunity and exposure to devastating natural elements are much reduced as a daily preoccupation. Moreover, residents have a higher likelihood of enjoying a longer history in Dhaka and more established social networks due to the desirability of the location.

Conversely, residents living at lower elevations most likely lack basic civic infrastructure and services and are susceptible to annual flooding whether through periodic river overflows or normal surface runoff during the monsoon season (Rashid, Hunt, & Haider, 2007, p. 95; Dewan, Yamaguchi, & Rahman, 2012, pp. 317-318). Whereas historic Dhaka mahallas were built around common water facilities, slum dwellers must share makeshift, unsanitary toilets and water fountains and are regularly exposed to industrial by-products from tanneries, hospitals, and other industrial plants (Kamal & Rashid, 2004, p. 108). Their social networks are also likely to be weaker and provide less opportunity than in the established areas. One study estimates approximately one-third of Dhaka slum dwellers to suffer from one or more diseases (Kamal & Rashid, 2004, p. 109).

Nevertheless, recent research on incentives to relocate slum dwellers out of flood zones indicates material incentives are insufficient in some cases due to the importance and strength of social networks and relationship-based safety mechanisms (Rashid, Hunt, & Haider, 2007, p. 103). This fact could indicate an important cultural predisposition to value human and family networks over material rewards and should inform research on how to effectively provide assistance. Geo-spatially depicting the results could lead to more precise targeting of development assistance.

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[1] For a more detailed analysis, please see Ashraf M. Dewan, "Vulnerability of a Megacity to Flood: A Case Study of Dhaka." *Springer Geography* (2013), pp.75-101. http://link.springer.com/chapter/10.1007/978-94-007-5875-9_3

Dhaka is divided into 90 official wards, each containing multiple mahallas. There are at least 1,200 slums with over 180,000 households in Dhaka (Rashid, Hunt, & Haider, 2007, p. 96). To dissuade unplanned urban growth, the government periodically bulldozes slum settlements and restricts the availability of social services. In the place of government, a slum mafia has evolved controlling access to land, business rights, and security (Rashid, Hunt, & Haider, 2007, p. 103). Geo-rectified link analysis and social network analysis could also enable analysis on barriers to effective aid distribution.

Civil society and non-governmental organizations (NGOs) have attempted to fill the governance void, providing support for income enhancing activities, basic education, and health services (Kamal & Rashid, 2004, p. 109; Habib, 2009). This activity has brought with it a political dimension since NGOs are characteristically believed to support the center-left, secular end of the political spectrum. NGO assistance to women in particular has brought violence from fundamentalist Islamist groups upon providers and recipients, including indigenous NGOs like the Grameen Bank (Shehabuddin, 1999, pp. 1012-1013; Rashiduzzaman, 1994, p. 975).

Socially, Dhaka's growth as an opportunity hub and manufacturing center is causing tensions along gender lines as well. The secular socialist, non-sectarian character of the independence movement created the conditions in which women believed they should be able to seek opportunity. Combined with the economic necessity of women seeking industrial employment, Bangladeshis are locked in a cultural struggle with Islamist parties over the acceptability of women walking to work and moving beyond traditional social space (Rashiduzzaman, 1994, p. 989). The fact that NGOs support many of these initiatives also politicizes their ability to aid Dhaka's most vulnerable.

Playing upon these natural and social vectors of instability are the political parties rooted in hartal politics. Liberals and centrists are comprised of the typical educated elite in the arts, media, politics, and NGO community while the Islamists can be found among madrassa students, professionals, military members, and civil servants (Rashiduzzaman, 1994, p. 976 & 983). Surprisingly, there is a growing cadre of Islamist or more pious women found among the educated and professional classes (Huq S. , 2011; Huq M. , 2008). Given Dhaka's reliance on industrial, educational, and NGO-related activities, it sits squarely in the middle of Bangladeshi social politics and has a high propensity for protest and disruption.

Conclusion

Understanding the culture of a population reveals much about the form, design, and function of city space. In this case, Dhaka's basic design follows the form and function of Bangladeshi ontology, which remains rooted in a community-based, familial organization unit. Though trappings of modernity lie over it, the mahalla matters to Dhaka's population and can serve as a basic unit of analysis for the RSI-Dhaka project. Instability in Dhaka will result from both socio-political and natural sources. Mapping out the political interests and alignments of the population will reveal much about the intensity of tensions between groups over time and allow for better data collection along the way. Similarly, understanding the specific needs of populations by mahalla will permit better targeting of development assistance to overcome the natural drivers of instability.

The M-RSI project can benefit markedly by conducting socio-cultural analysis on a population to reveal the cultural logic of city design. Dhaka is a particularly interesting case because it fuses a traditional ontology with modern city design. Fortunately, much of the research for generating baseline understandings of a population already exists in academia. Future M-RSI efforts can benefit similarly and make good use of subject matter experts in the design phases.

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Chapter Four, Black Spots Are No Treasure Island: Land Tenure and Property Rights in Megacities

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Abstract:

This chapter addresses the geographic phenomena of megacities, urban areas with over a population over 10 million. It examines the pace of rural-to-urban migration, its promises of a better livelihood for 180,000 who daily migrate to cities, but for billions of people in the coming decades, the perils of slum proliferation. The term "Black Spots" is borrowed from Bartosz Stanislawski to describe urban areas beyond the reach of municipal governance. Megacity slums dwellers lack basic services, but none so debilitating as a lack of land tenure and property rights. Three new tools are discussed which can help decode the human geography of megacities and thus inform future urban operational decisions: an international standard for land administration, volunteered geographic information, and dynamic map data to support humanitarian missions.

Keywords

Urbanization, urban, city, megacity, ungoverned space, demographics, slum, land tenure, property rights, governance, migration, development, land administration, humanitarian assistance, disaster response, volunteered geographic information.

Introduction

The city of London's population increased from one million to its peak of eight million on the eve of WWII; a process which took place over the course of a century. Karachi, Pakistan, however, added more than eight million new residents in just the last decade! With a population of over 23 million, Karachi is now the third largest city in the world! Centenarians in Bangladesh's capital city have witnessed a 30-fold population increase in their lifetimes that has also transformed Dhaka into a *megacity*, defined by the United Nations as population centers of over 10 million. Security expert Robert Muggah refers to this breakneck pace of rural-to-urban migration as "turbo urbanization," and further suggests that the global rise of megacities offers both promise and peril. Megacities are increasingly becoming the focal point for economic growth, diplomatic wrangling, and developmental aid (Muggah 2013). Indeed, one week after Muggah posted his article, *Megacity Rising*, the U.S. Agency for International Development (USAID), shifted its 50-year focus on alleviating rural poverty to include stark urban realities. Associate Administrator Mark Feierstein, upon releasing USAID's "Sustainable Service Delivery in an Increasingly Urbanized World" policy," noted that

> One billion people currently live in slums without access to basic services like clean water, electricity or health services. USAID's field programs need to plan for the challenges that come along with rapid urbanization so we can more effectively help these communities reach their economic potential and

> alleviate poverty...An estimated 180,000 people move into cities **each day** (bold font mine). This policy will help USAID and the development community to respond to the needs of the 1.4 billion who will have moved into urban areas between 2011 and 2030 (USAID 2013).

In the 1970s, there were only three megacities on planet earth; by many counts there are now 24 of these municipal behemoths with another dozen expected to appear over the next decade. This paper examines one aspect of the security and governance perils posed by rapid urbanization and megacity growth. It also suggests new assessment tools in order to analyze and understand the socio-political dynamics that can inform new governance policies and processes suited to the megacity phenomenon.

Black Spots

In the pirate lore of Robert Louis Stevenson' *Treasure Island*, black spots symbolized the collective, malignant will of miscreants. When rural-to-urban migration is tracked by business, voter, vehicle, property and other civil registrations, migrants and the gaining municipality both stand to benefit. However, when local governments remain uninformed about new arrivals and their needs for basic services, much more foreboding Black Spots, but with no less group malice, inevitably form. Dr. Bartosz Stanisławski, of the Maxwell School of Citizenship and Public Affairs at Syracuse University, defines these atrocious, geographical Black Spots as

> parts of the world that are (1) outside of effective governmental control; (2)controlled, instead, by alternative, mostly illicit, social structures; and (3) capable of the breeding and exportation of insecurity (e.g., illicit drugs, conventional weapons, terrorist operatives, illicit financial flows, strategic/sensitive know-how) to faraway locations. Similar to the notion of "black holes" in astronomy which are located mainly by analyzing anomalous gravity fields, black spots are also difficult to "see," as they usually, or for extended periods of time, operate with a high degree of "international invisibility"(Stanislawski 2010).

But the proactive Stanislawski is more than a mere coiner of novel terms. His Mapping Global Insecurity project is best viewed as an "intelligence support activity that through research and analysis can provide real-time crisis support, enable new and unique insights, 'tip' other intelligence collection, 'cue' further classified research and analysis, and lead to the discovery of new requirements within the Intelligence Community (IC)" (Stanislawski, 2013). He further contends that Black Spots are not the same as failed, failing, or weak states, and as such, create very difficult security challenges. Indeed, Black Spots are nothing to be treasured; they are uncharted islands in billowing seas of massed humanity, imperceptible to the IC's classic sensors. His project uniquely discovers Black Spots through the triangulation of data regarding anomalous events and transfers in particular regions. "Mapping them allows us to be one step ahead of the so-called 'global bads'… it is our task to scan for them, pinpoint them, and monitor them" (Stanislawski 2013).

Dr. Geoffrey Demarest, a researcher at the U.S. Army Foreign Military Studies Office, would be pleased with the work of Stanislawski's Mapping Global Insecurity project.

For over a decade, Demarest has "advised industrial-level GIS (geographic information systems) cadastral (land and property registry) projects for countries of special interest," (Demarest 2004) and pleaded for the U.S. and UN not to continue to place property formalization on a secondary plane of goals. A polity that does not formalize ownership rights and duties, especially rights and duties related to land, will not enjoy peace. Comprehensive, precise and transparent expression of real property is a necessary precondition of peace, adjures Demarest. "Places outside the lines of formal property necessarily slump toward possession by force….The process of formalizing property, moreover, illuminates power and power relationships. It also exposes the otherwise invisible lines of communication and sanctuary that power over places provides" (Demarest, 2008, p .iii). Demarest further sketches how illegal armed groups (IAG) pursue and enjoy eight principal, overlapping uses of urban slum land in relation to their illicit pursuits. These eight land uses, in no particular order, are: 1. taxation; 2. free trade; 3. sanctuary; 4. clandestine manufacture or processing; 5. staging for violent operations outside the slum; 6. safe transit of contraband; 7. recruiting; and 8. as a prison or graveyard for their victims.

> The eight categories could be used as part of taxonomy for geographic profiling (predictive geographic forensics). The IAG land-use categories are suitable as variables (field descriptions or attribute names – the titles of the columns at the top of an SQL spreadsheet perhaps) in a forensic police/military GIS data table. While such use of GIS may be the most immediate or directly relevant application to government reduction of illegal armed groups, other uses, such as informing urban building and street design, may yield the more important longer–term security benefits (Demarest 2011).

Demarest, a noted Colombia analyst, would likewise be pleased by "The Medellin Miracle" (Colby 2012). The city's grim past of violence, drug lords, guerillas, and paramilitary death squads has been radically transformed by political will and social inclusion, from the most dangerous city in the world to a showcase of urban renewal and even host of the UN's World Urban Forum VII in April 2014.

A Plurality of Urban Power Brokers

Over the past dozen years, the U.S. has been militarily and politically transfixed on Iraq and Afghanistan. As a result, stupendous socio-demographic trends in the developing world have received scant notice. These include the aforementioned rapid urbanization: 70 million new urbanites annually, the equivalent of two new Tokyos, appear on the earthscape (Engelke 2013); the emergence of sub-state entities and privatized versus state-delivered services; and, from urban centers, where political consciousness is first formed, the growing demand for participatory governance that sparked the Arab Spring. Indeed, future operational environments are scarcely recognizable from the pre-9/11 era.

Recent rural-to-urban migration has resulted in 23 urban agglomerations that can be classified as megacities. By 2025 there will likely be 37 megacities (Jones 2012. p. 38). Despite a rapidly rising middle class, one billion urbanites eke out a living in informal settlements (slums) worldwide (UN HABITAT 2005). Slum dwellers lack infrastructure; yes, photographs of urban squalor are shocking, but more significantly, they lack any documentable land tenure and property rights. Terrorists, insurgents, crime bosses, narcotics and human traffickers, and slum lords well understand the power informal settlements offer for the taking. Harrowing scenes from a 1992 film (City of Joy) depict how eagerly nefarious actors await the next billion-person vulnerable cohort expected to join the current one billion slum dwellers by 2030 (The Boston Globe 2012). Unimaginably, Africa, the last continent to urbanize, by 2030 may become fifty per cent metropolitan as well (Jones 2012, p. 37). Without little to any industry providing the newcomers with jobs and livelihoods, they nevertheless organize themselves into place-based ethnic enclaves, informal shadow economies, and intricate social networks. The governance vacuum, to include land governance, is quickly filled by other actors.

> Fundamentally, land governance is about power and the political economy of land. Land tenure is the relationship among people with respect to land and its resources. The rules of tenure define how access is granted to rights to use, control, and transfer land....they develop in a manner that entrenches the power relations between and among individuals and social groups (FAO 2009).

Shielded by anonymity and impunity, purveyors of instability hide in unregistered properties, and use the wealth hidden in those properties to fund their illicit activities. They decide who gets what by imposing their own "property ownership" regimes on the local populace; they offer services to offended claimants, create loyalties and obligations, and sow fear (Demarest 2008, pp. 277, 286). This dynamic is illustrated in Sandra Joireman's research on property rights enforcement mechanisms in a Nairobi slum. She identified three sub-state entities in Kibera —a pocket of statelessness located directly in the geographic center of power in Kenya — that have emerged to fill the void left by a state that lacks the political will to resolve land disputes. Non-governmental organizations (NGOs), the first type of non-state entity, conduct alternative dispute resolution because the government is perceived as aloof (offering bureaucratic forms to fill out at unaffordable costs), ethnically biased, or corrupt (demanding bribes). The second alternative is government officials who, outside their formal authorities, misuse their positions to resolve disputes for personal enrichment. The notorious, third option is ethnic gangs who run protection rackets and use violence and intimidation on behalf of clients seeking redress (Joireman 2011).

Professor Seth G. Jones cites a number of reasons why insurgents have historically favored rural areas as their base of operations. This assumption also will have to adapt to 21st century changes: insurgents and their ilk may well shift their operations to urban areas in order to avoid the lethal scrutiny of drone aircraft. Jones also ascribes to rural areas the advantage that "government security forces often have better intelligence penetration in urban settings" (Jones 2012). That rings true where governments prize transparency of property ownership and land use. Sadly, that is not often the case for the slums of the world's megacities, where government officials (or their well-placed relatives) benefit from the status quo in terms of social power and profitable rent schemes. Dr. Peter Engelke, Senior Fellow at the Atlantic Council and co-chair of the Urban World 2030 working group contends that megacities are the most complex problem in the history of humankind. "We have seen the future and it is urban!" (Engleke, 2013) Others share his concern "that poor planning and governance of developing world megacities---including the failure to positively engage slum dwellers---will both diminish national economic growth and leave behind a huge urban underclass” (Liotta and Miskle 2012) (Commins 2011) (Davis 2006).

Yet Engelke offers a prescription: “the world’s foreign and security policy establishments must not only become more cognizant of mass urbanization, but begin creating the processes that will productively integrate cities with global governance structures” (Engleke, 2013). Dr. James Knotwell, a Regional and Geospatial Scholar with the Cultural Knowledge Consortium (CKC), recently surveyed megacity literature in four informative CKC blogs (Knotwell, 2013). With a tone concordant with Engelke’s analysis, he appreciates what lies beyond the pervasive images of megacity poverty.

> These impoverished urban groupings are, at the same time, highly enterprising and resourceful in creating their own informal infrastructures and integrating these in the more formal, state-originated, networks of assistance and support. This demonstrates a critical change in analytical perspective that leads decision-makers of potential interventions, be they development or security-related, in a different direction from those subscribing to former CDP [colonial/dependency/poverty] explanatory models, re-orienting these institutions (which will include military/NGO) *toward* the locality/neighborhood and its inherent power structure and *away* from the representatives of state power brokers. It also demonstrates the utility of investing resources in identifying those local power networks (Knotwell 2013)

According to futurist Mike Davis, “Slum populations can support a bewildering variety of responses to structural neglect and deprivation, ranging from charismatic churches and prophetic cults to ethnic militias, street gangs, neoliberal NGOs, and revolutionary social movements.” How future U.S. defense, diplomacy, and development efforts might identify and positively engage megacity power brokers is the subject of the next section.

Megaproblem: 4.5 Billion Unregistered Properties

By 2030, sixty per cent of the world’s population will live in cities, with the most explosive growth occurring in developing countries (UN 2013). Conflicts in megacities will inevitably occur and they will be increasing horrid. Future U.S. operations abroad, of any scale, will now most likely encounter multiple actors in dense, urban environments where shaping and winning the information domain invariably will include a robust knowledge of how persons are tied to places.

Land administration, a discipline scarcely known in the U.S., is the process of determining, registering, and disseminating information about the relationship between people and land (ISO 2013). Until a decade ago the preferred way to confer land rights upon individuals and groups across the globe had been through formal land titling administered by the state. A new paradigm has recently emerged, recognizing a continuum of rights and interests in land, one inclusive of individuals and groups who live in megacity slums and other areas where formal titles are not the norm, or not accessible or affordable. Registered title (or deed) ownership of land, common in only 50 or so developed countries, account for 1.5 billion land parcels. The remaining 4.5 billion of the world's estimated six billion land parcels are held informally and are thus susceptible to disputes, land grabs, environmental degradation, food insecurity, and social unrest (McLaren 2011).

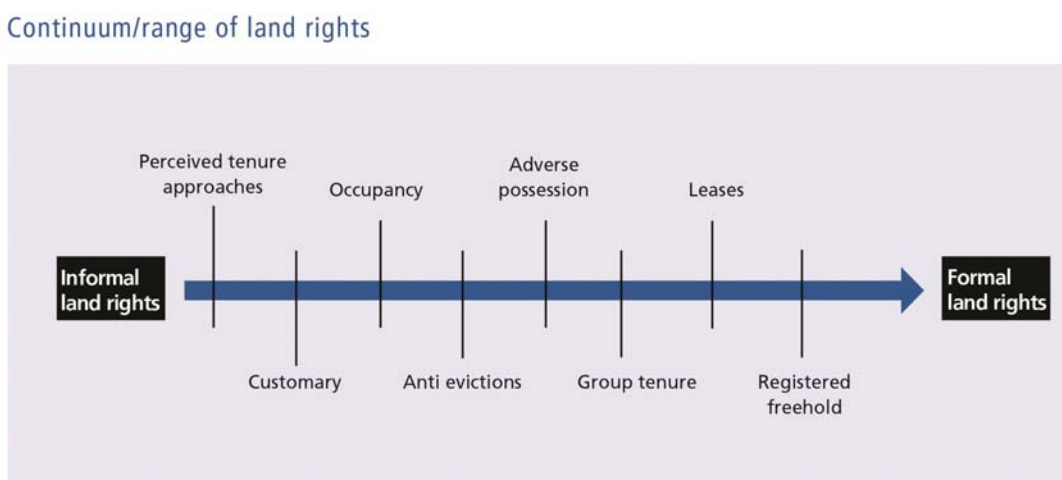

Figure 11: Continuum of Land Rights.

Thus, the continuum, from left to right, begins with informal land rights, which are usually oral agreements, and then customary tenures, both relied upon by poor and marginalized populations (Deininger et al, 2011). Certificates of occupancy, while not enabling the holder to sell or lease, do provide a measure of tenure security against predatory slum lords and unscrupulous customary or government authorities bent on eviction. Group tenure is much easier to secure than individual tenure. Efforts to formalize group tenures in land administration systems (LAS) have also done much to improve the livelihoods of people at risk of losing their communal land rights in land grabs and other wicked schemes. The authors of a primer on global land administration concur:

> LAS are about formalizing tenure, irrespective of its local form and content, whether it's short-term occupation rights or full ownership. Simply, land administration is about formal systems. We don't apologize for this. We accept that informal systems are essential parts of any system of society, but without organizing a coherent, formal system for administering land...a country or society will be doomed to poverty. This does not mean that that the formal system needs to be complicated, national in scale, or expensive (Williamson et al 2010).

Cadastres provide a degree of systematic clarity in identifying owners, spatial extents, and rights and interests over land. When official or authoritative data is lacking, an increasing number of land agencies are recognizing the potential utility of crowd-sourced information. Volunteered geographic information can be harvested to help address---and redress---the billions of unregistered land rights and interests that need better visibility in the immediate term –regardless of whether they represent full ownership or not (McDougall et al 2013). Moreover, there are now advanced Information Communication Technology capabilities that can accomplish such a herculean feat. The final section examines three of these.

Tying People to Land Interests: The Human Geography of Megacities

The hundreds of millions of people informally residing in Black Spots are often invisible to their governments and international actors because their secondary land rights are not documented. Fortunately, three new tools have recently become available to help decode the human geography narrative of megacities.

An International Standard for Land Administration

A decade-long effort in land administration recently achieved a strategic breakthrough and, on a per capita basis, informal settlement populaces stand to reap substantial benefits. In November 2012, the Land Administration Domain Model (LADM) became the first international standard for the unsung discipline of land administration. ISO 19152 provides an abstract, conceptual model with three packages related to:

- parties (people and organizations);
- basic administrative units, rights, responsibilities, and restrictions (ownership rights);
- spatial units (parcels, and the legal space of buildings and utility networks); with sub-packages for spatial sources (surveying), and spatial representations (geometry and topology) (Lemmen and van Oosterom 2013)

Based on the LADM, the Social Tenure Domain Model (STDM) is an initiative of UN-HABITAT to address land tenure gaps such as those found in Black Spots. It identifies relationships between people and land independent of levels of formalization or the legality of those relationships. The STDM enables comparisons of peoples' hold on land across cultural and political boundaries. The linkage of people to informal settlements is done by capturing best available evidence: water and electrical receipts, ground photos, recorded oral testimony, copies of leases, etc. By potentially including every human being in some form of LAS, the STDM can contribute to poverty reduction, as the land rights and claims of the poor are brought into the formal system over time. It opens new land markets, and aids development by equipping urban communities with land management skills. While the advent of LADM/STDM offers cheery news for slum dwellers, spatial entrepreneur Jill Urban-Karr admonishes that turning the LADM/STDM from a conceptual into a logical model that describes cadastral data requirements for an actual urban environment is an often overlooked next step for ISO 19152's implementation. To this end, she and her colleagues examined data correlation between LADM-based logical models and case studies in Belize and Victoria, Australia. Their evaluation positively compares the case studies against the same model in an ArcGIS geodatabase (Kalantari et al 2013).

Volunteered Geographic Information (VGI)

Black Spot residents may, at times, be invisible, but they are no longer silent. In 2008, the notorious Nairobi slum of Kibera was wracked by post-election violence and displacement. At the time, the slum of at least 250,000 Kenyans was "a blank [black] spot on the map until November 2009, when young Kiberans created the first free and open digital map of their own community. Land ho! The excitement felt by Stevenson's seafarers upon sighting land following a long sea voyage was replicated by a quarter-million Kibera slum dwellers, who "saw" their land depicted on a chart for the first time. Map Kibera has now grown into a complete interactive community information project (Map Kibera 2013). Military geographers at the National Geospatial-Intelligence Agency (NGA) vetted the Map Kibera data, to include spatial extents of the named neighborhoods of this extraordinary participatory mapping project. Citing it as "best available data" over Kibera, they deviated from their decades old practice of using only official host nation government cartographic sources, and coded the Kibera neighborhood names as U.S. Board on Geographic Names (BGN)-approved toponyms. NGA added the Map Kibera place names to its publically available Geonet Names Server (NGA 2013) weeks before the March 2013 Kenyan elections (Foster and Batson 2013). Had Kibera again convulsed in mayhem, first responders and international actors would have been much more informed about Kibera's human geography. That political violence in the 2013 election cycle was minimal was no accident. Map Kibera and other Kenyan NGOs banded together to form the Kibera Civic Watch Consortium, a network to respond to and coordinate the community's efforts to maintain peace and provide interventions where possible. According to Erica Hagen, co-founder of Map Kibera, "a sea-change is underway in terms of how people engage with information in Kenya: they feel it's their right and responsibility to speak out and to protect peace by countering rumor; and they increasingly feel they have tools with which to do so" (Hagen 2013).

One of those tools is the mobile telephone; in megacities, they are many times more prevalent than toilets. Crowd-sourced data maven Robin McLaren notes how cell phones progressively integrate satellite positioning, digital cameras and video capabilities. In the hands of even the poorest slum dweller, they provide the opportunity to directly participate in the full range of land administration processes from videoing property boundaries to secure payment of land administration fees using "mobile" banking. But even today's simpler phones … would allow a partnership to be established between land professionals and citizens and would encourage and support citizens to involve themselves in directly capturing and maintaining information about their land rights. Crowdsourcing initiatives in land administration may coalesce into a much wider open data phenomenon similar to the global OpenStreetMap initiative. If this happened then a free and open source software solution to store and manage the crowd-sourced land administration information would be created and populated by volunteers (McLaren 2013).

More guarded in their optimism about the value of VGI for land administration are Andrew Frank and Gerhard Navratil of the Technical University of Vienna. The Austrian geoscientists believe that VGI can provide information on topics where direct observation is possible, for example, occupation and use of land. Rights over land, however, the forte of land administration, cannot be observed directly by citizens with local knowledge because they are not observable. They suggest that publically-sourced data might provide an advantageous perspective, e.g., land use data in contrast to land cover data provided by remote sensing, and serve as supporting information to VGI (Navratil and Frank 2013). In any case, the activities surrounding crowdsourcing and VGI not only serve the primary purpose of documenting the spatial and social dimensions of Black Spots, they also build the political, and even entrepreneurial, capacity of women, disabled, and youth---the poorest of the poor. Of all the deprivations slum dwellers face, political exclusion is the most destabilizing for megacities.

Dynamic Map Data Supporting Humanitarian Assistance & Disaster Response

Third, while U.S. government agencies, especially those tasked with humanitarian assistance and disaster response (HA/DR), would agree that local knowledge should inform operational decisions; they nevertheless wrestle with how to treat volunteered versus "authoritative" geographic information. The unorthodox answer to this dilemma is not "either/or" but rather both! The Rapid Open Geospatial User-driven Enterprise (ROGUE) is an interagency project under development by the U.S. Army Corps of Engineers. ROGUE offers the capability for organizations to collaboratively develop, manage, and share geographic feature data with traditional and non-traditional partners. This new, rogue paradigm allows authoritative geographic information and VGI to coexist. An improved OpenGeo Suite ingests, updates, and distributes non-proprietary feature data utilizing open source software and open standards---such as the LADM/STDM.

> The authoritative organization can make certified copies (versions) available, and most users would clone or fork it according to their needs. They could work on a dataset outside the main repository or push the changes back to the authoritative organization. Either way, those individuals in charge of the central repository would be able to pull the new changes and incorporate them into their quality assurance process before publishing the changes as an updated version (Clark et al 2013).

By integrating these capabilities with Pacific Disaster Center's DisasterAWARE platform and the Department of State Humanitarian Information Unit, the DoD, and mission partners, are able to plan, analyze, and collaborate using dynamic map data supporting HA/DR and other geospatial collaboration scenarios. The development of GeoGit (a set of data repository-creating utilities) is the cornerstone of ROGUE. It allows for distributed collaboration and versioning of geographic data. GeoGit will provide the ability to maintain a history of the changes to geospatial vector data, track who made the changes and when, and store comments on the reasons for the changes.

> GeoGit is fundamentally different from previous geospatial versioning efforts in that it is designed to support distributed operations at its core. It does not rely on network connectivity to be fully functional. GeoGit is designed to handle projects that have a very large number of contributors (Clark et al 2013).

ROGUE seeks to improve mechanisms for tracking, managing, and curating data. It posits that collaboration is maximized by putting the user at the center of the infrastructure and encouraging data contribution. Perhaps more importantly, enhanced situational awareness is gained from a bevy of internal and external viewpoints about the data and current ground truth.

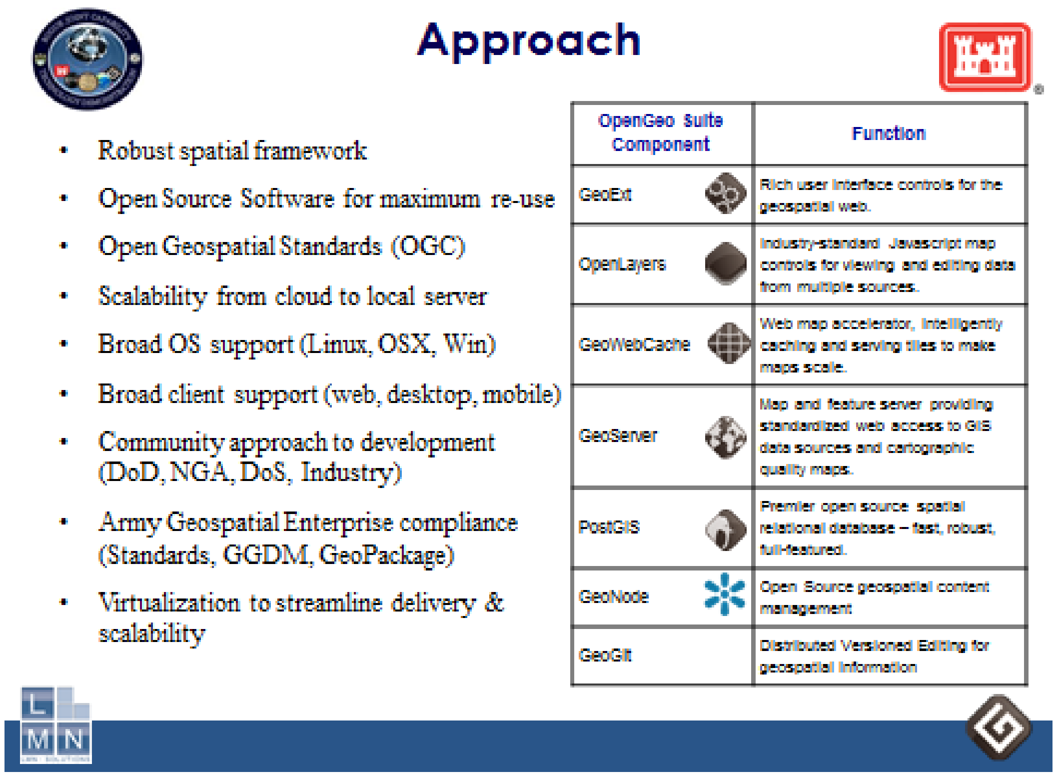

Figure 12: The ROGUE Approach Courtesy of LMN Solutions

Conclusion

In the world's Black Spots, power brokers rise and fall with little notice by those in official positions of power. But as megacities are increasingly engorged with more people who receive inadequate municipal services, a key non-state actor's (an individual or group) demise has the potential to collapse not only a city, but an already fragile state connected to the massive urban engine. Remotely sensed imagery can detect a number of physical and human "patterns of life" changes. But Black Spots leave little evidence with which to gauge what is normal to begin with, namely, a dearth of information on who occupies and controls land.

Dhaka, Bangladesh, a fast-growing megacity of over 14 million residents, is situated on the world's largest river delta, the Ganges-Brahmaputra, effectively surrounding it by water. It is thus prone to multiple natural hazards, namely, monsoon flooding and ocean typhoons. "If water doesn't pose enough risk, Dhaka sits close to three active seismic fault lines – the Madhupur, Dawki, and Himalayan faults – for which a big tremor is overdue" (Open Cities Project 2013). Dhaka's 5.5 million slum dwellers are at grave risk for a mega-disaster. Fortunately, Dhaka is a megacity in which publically-sourced data is obtainable. The Open Cities Project graphically portrays data on Dhaka's building conditions, inhabitants, and associated risks; building plans, use, and other infrastructure use. A totally separte effort, Global Housing Indicators (GHI,) creates data for housing practitioners to use as a standard way to collect information about housing policies across cities and countries (GHI, 2013). According to Robert Lopez, a human geographer at NGA, crowdsourcing could well reconcile discrepancies between GHI's recently published full assessment of Dhaka's housing and Open Cities' metadata on Dhaka's buildings, and thus alert citizens and municipal authorities to the people at greatest peril.

Similarly, the LADM/STDM can overcoming previously vexing constraints by enabling municipal authorities to record informal land tenures alongside statutory ones. Crowdsourcing and VGI can alert them to which megacity neighborhoods demand attention so that they might not fall under the sway of rogues. Finally, ROGUE can inform USG operational decisions with both volunteered and authoritative geographic information. A century-long precedent in USG exists for such an approach. By publishing millions of BGN-approved foreign place names and their standard spellings, but also millions of variant and unverified names of geographic features used by ethno-linguistic groups beyond a nation's official language, NGA's GeoNet Names Server is a treasure trove of human geography information. The complexity of actors and factors surrounding megacity land matters demands the fusion of volunteered and authoritative information. New tools are available to harvest that information and extend governance to the globe's Black Spots. The *Jolly Roger* will then, as it did centuries ago, fly only over a few uncharted desert isles and not over populous megacity enclaves.

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Chapter Five, Urban Socio-Cultural Monitoring with Passive Sensing

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Abstract

The most challenging operational requirement in localized social-cultural situation assessment (SCSA) is to provide timely, local information for tactical operators often located in remote, often hostile, small towns and villages, and potentially denied areas. This challenge has led us to investigate the non-traditional concept of collecting SCSA data using in-situ sensors. Our approach is to use this data to update local models and reason about changes in the local area of operation (AO)'s atmospheric state in terms of grounded social-cultural and PMESII variables and Pattern of Life event anomalies. In this paper, we provide an overview of the insights provided by this system, its theoretical underpinnings, and the sensor processing techniques employed. Based on lessons learned from this effort, we also present a collection of critical research and operational gaps related to the Megacity-RSI effort, providing a basis to apply those lessons to reason about changes on the megacity scale.

Keywords

Socio-cultural situation assessment (SCSA), sensor networks, Patterns of Life (POL), atmospherics, human sensing

The Urban Socio-Cultural Monitoring Challenge

The recent SMA study on Megacity-RSI pointed out that remote sensing data alone will be insufficient and needs to be supplemented with ground-level field and social science data (M-RSI SMA, 2012). Unfortunately, there are significant gaps today in collecting timely ground-level field data using traditional censuses, polls, and surveys at the same global scale and frequency as is possible with remote sensing. This gap is especially true in remote, hostile, and potentially denied tactical areas where units require updates commensurate with the battle rhythms of their adversaries, which is measured in hours and minutes (Flynn, 2012). In this chapter, we describe several recent and ongoing efforts at Charles River Analytics focused on developing a capability to assess social-cultural systems in support of modern mission requirements. The key feature of these efforts is a novel focus on in-situ passive sensors and social-cultural models locally calibrated to provide information unavailable from remote sensing. We report our results and lessons learned below in the context of the gaps identified in the prior UM-RSI SMA studies. In particular, we feel that this work may address the problem of missing ground-level data about changes in atmospheric indicators and Pattern of Life (PoL) anomalies that are invisible to two primary sources of emerging importance: remote sensors of any type/altitude, and social media sources. We believe that unprecedented socio-cultural awareness of megacities is within reach by extending the approaches described in this chapter. We will describe examples that include image-based atmospheric indicators that are visible from a horizontal vantage point (e.g., pedestrian gender, ratios of children/adults, gestures, gait) and acoustic indicators (e.g., decrease/increase in ambient sound level, friendly/angry yelling, laughing, gunshots). In this chapter, we advance the idea that in-situ sensor collection and localized models will address some of the inherent concerns for providing timely ground-level data to better understand social atmospherics and changing conditions.

A Sensor-Based Approach to Social-Cultural Data Collection

The most challenging operational requirement in localized SCSA is to provide timely and local social-cultural information for warfighters and operators often located in remote, hostile, and potentially denied areas. This challenge led us to investigate the non-traditional concept of collecting SCSA data using in-situ sensors. The system concept is to use this data to update local models (Heimann 2013) and reason about changes in the local AO's atmospheric state in terms of grounded social-cultural and PMESII variables and Pattern of Life event anomalies.

We initially investigated the use of in-situ passive sensors based on successful demonstrations of automated recognition of non-verbal social signals from facial expressions related to basic hidden emotional states (e.g., anger, fear, happy, sad, surprise, and disgust) (Ekman 1957; Picard 1995). The initial "affective computing" demonstrations based on facial cues were expanded later to multiple social signals from hand gestures, posture, and voice characteristics (Picard 1995; Pentland 2004; Vinciarelli 2009).

Early on, we identified several conflicts between sensor resolution required for facial cues and program requirements for group-level observation, as well as potential problems with causal ambiguity of affective cues. These conflicts led us to conduct two concurrent literature searches, one for variables grounded in social science theories, and a second search for applicable sensor and indicator feature detection algorithms. We also included the sensing of visible and audible indicators of SCSA variables from Field Manuals for counterinsurgency (FM 3-24) and human intelligence collection (FM 2-22.3).

Social and political scientists traditionally collect group-level data using unconstrained survey/poll questions. Unfortunately, this process requires human interpretation about indicators that could not be directly observed or sensed, e.g., food supply, grievance level, quality of life, unemployment, legitimacy, level of crime (Goldstone, 2010). This aspect presented a significant difficulty, and is probably the key reason that little work has been done previously on sensor-based data collection. To address this difficulty, we investigated further into the social science literature to identify underlying observable behavior indicators related to the theory-based variables and then proxy indicators that could be sensed. For example, unobservable "food supply" values could be approximated by the relative "number of individuals in a marketplace mid-day", which can be measured directly with appropriately placed sensors. Social scientists go to extreme lengths to confirm that their survey-based variable measurements provide pier-reviewable support that their measurements reflect an intended theoretical concept (Glaser & Strauss 1967; Carmines 1979). As a result, many social scientists may reject these "proxy" means of measurement. However, the focus of our work is to provide actionable intelligence, rather than support the refinement of social science theories. Our results have shown that we can in fact collect automated measurements of changes in social indicator magnitude and direction that correlate with real changes in local social conditions.

In operations, the DoD uses the holistic set of six well known and widely accepted PMESII variables (Political, Military, Economy, Social, Infrastructure, Information).[1] As a result, because our operational user requirements for SCSA information are in terms of PMESII variables, we had to devise a mapping of the six categories of PMESII variables to social science variables. The result is a three-stage mapping from PMESII variables, to grounded social science variables, to low-level indicator measurement variables that can be sensed. The complete catalog of this mapping across the six PMESII variables has grown quite large after several years of iteration. For illustration, a simplified version for one of the six variables, the social or "S" variable, is shown in Table 1. At this early proof of concept stage, this three-stage mapping has only been informally validated with limited data collection. However, the general coverage at the level of social science variables corresponds to similar conflict related structural variable models contained in other "large-scale" models we have identified (Astorino 2012; Salerno 2013; Maybury 2010; Chamberlain 2013). The significant difference is that these large models are primarily at the strategic, not tactical, level and they do not rely on sensor data. The list of sensor variables that we developed appears to be novel and can likely be adapted to M-RSI and other systems.

Table 1: Mapping from PMESII to Social Science to Sensor Variables

<table>
<tr><th>DoD FM 3-0 Variables</th><th>Social Science Variables</th><th>Sensor Variables</th></tr>
<tr><td rowspan="4">• Demographics
• Foreign Populations
• Quality of Life
• Terror Events
• Migration</td><td>• Social Capital
• Sense of Community
• Feelings of Membership
• Feelings of Support
• Shared History
• Ethnic Fractionalization</td><td>• Evening Teahouse/Restaurant Traffic
• Mosque/Church Attendance
• Pedestrian Couples
• Public Celebrations</td></tr>
<tr><td>• Demographic Pressure
• Ethnic Mixing
• Youth Bulge
• Environmental Pressure</td><td>• Population Density
• Age and Gender Distribution
• Tribal Dress Ratios</td></tr>
<tr><td>• Life Conditions
• Neighborhood Audits
• Physical Disorder
• Quality of Life
• Missing Shoes
• Air Pollution</td><td>• Inward Morning Trucking
• Morning Market Traffic
• Overall Human Activity
• Image Entropy
• Shoeless Individuals
• Atmospheric Condition</td></tr>
<tr><td>• Sense of Security
• Graffiti</td><td>• Unattended Women/Children
• Pets/Joggers</td></tr>
</table>

[1] While PMESII is sometimes criticized based on being originally designed for CMO targeting, it has been supported and largely adopted as providing a common sharable framework for COIN situation assessment as well as being linkable to the Military Decision Process (MDMP) because it can be easily trained and provides useful real world data about the area in which a unit operates http://afghanquest.com/?p=457

	• Civil Violence • Explosions, Crowd Noise • Trash Accumulation	• Trash

In addition to constructing the social science variable and sensor variable catalog, we have built a second catalog that links the sensor variables to a list of sensor feature extraction primitives, associated sensors and feature extraction algorithms. This catalog was divided into three sensor range categories: "micro" close-up signals, "meso" intermediate range signals, and "macro" signals which start to overlap with traditional remote sensing data. A small subset of this catalog is listed in Table 2.

Table 2: Social signal inventory

	Social Signal	Feature Primitives	Sensor	Collection Difficulty
Micro	Non-Contact Remote Physiological Signals			
	Stress/Agitation	Temperature changes	IR, Hyper-Spectral	High
	Stress/Agitation	Blood pressure, respiration rate	MRI, NIRS, fMRI	High
	High-Resolution Individual Human Signals			
	Known Faces	Biometric face match	Video, BAT/HIIDE	High
	Auditory Cues	Tone, intensity, rate/prosodity	Audio	Low
Meso	Medium Resolution Individual Human Signals			
	Body Pose	Skeletal features	Video	Medium
	Body Shape/Gender	Anthropometric cues	Video	Medium
	Aggregated Group/Crowd Signals			
	Car & Foot Traffic Statistics & Patterns	Number, time, type, direction, velocity	Video, Acoustic, Seismic	Low
	Local Neighborhood			
	Service Quality (e.g. trash pickup)	Volume, rate	Video	Low
	Air Quality	Aerosols, NO2,CO2	Electrochemical/IR	Low
	Ambient Noise	Volume, regularity	Audio	Low
	Local Weather	Temperature, barometric readings	Generic Weather Sensors	Low
Macro	Village/Town Signals			
	Foot or Vehicle Paths	New path appearance	Video	Medium
	Presence of Electricity	Power monitoring, night-time glow	Remote Sensing	Low
	Migration, Diaspora	Vehicle, pedestrian traffic streams	Remote Sensing, Mobile Device Tracking	Low

In-Situ Sensors and Sensor Processing

The initial in-situ sensors included a single wide-angle video camera at building roof level and an Unattended Ground Sensor (UGS) that included a seismic sensor. In the second generation, the video camera was replaced with a small Android-based camera, and the seismic sensor has been augmented with an acoustic sensor. We have found that the acoustic sensor detects relatively equivalent events in an urban setting (as opposed to a battlefield sensing) with significantly fewer installation issues. Examples of data collection and feature extraction are shown in Figure 4 & Figure 5.

Figure 13: In-situ sensing, tracking pedestrians

Figure 14: Using video to track vehicles and pedestrians on the same backdrop

Model Implementation and Sensor Data Conditioning

Six Bayesian networks were constructed for each of the categories of PMESII variables, as illustrated by the simplified example for the Social ("S") variables shown in Figure 6. The occurrence of detected social signal indicators by the system sensors are transformed into spatial/temporally contextualized measurement variables by a relatively complex process that embodies the mappings identified in Table 1.

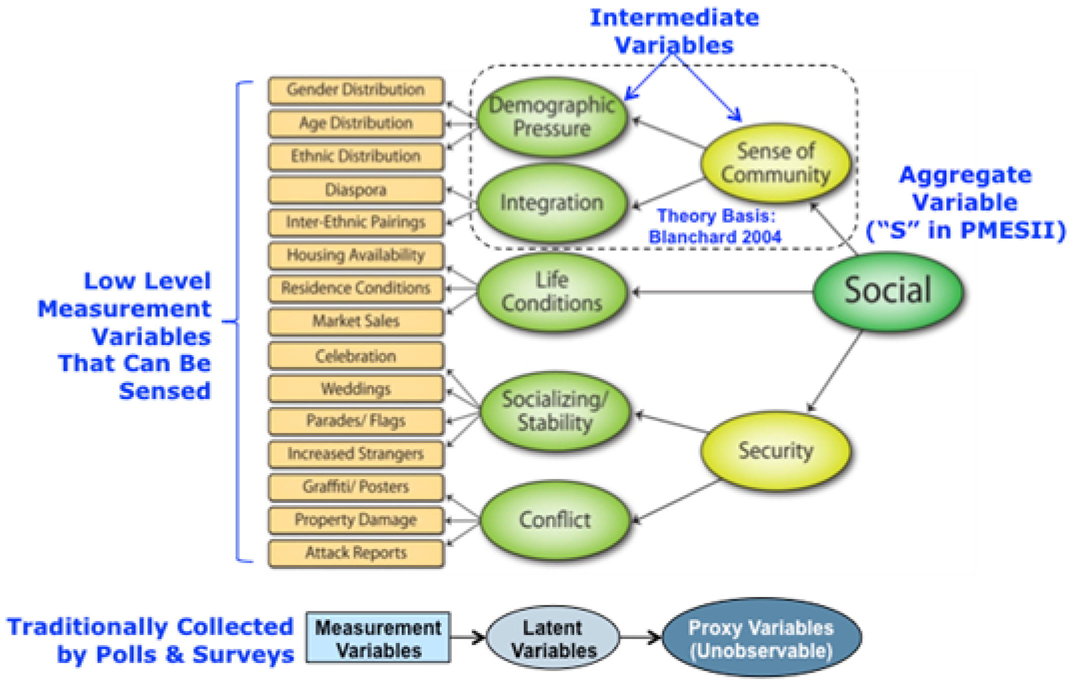

Figure 15: Bayesian Network Example for PMESII Social Variable

The outputs from the PMESII Bayesian networks are stored daily in a database to enable their display on a spider graph to compare to past values. An example of that spider graph is shown in **Error! Reference source not found.**. Although not illustrated here, there are also functions for alarms, tips, and cues.

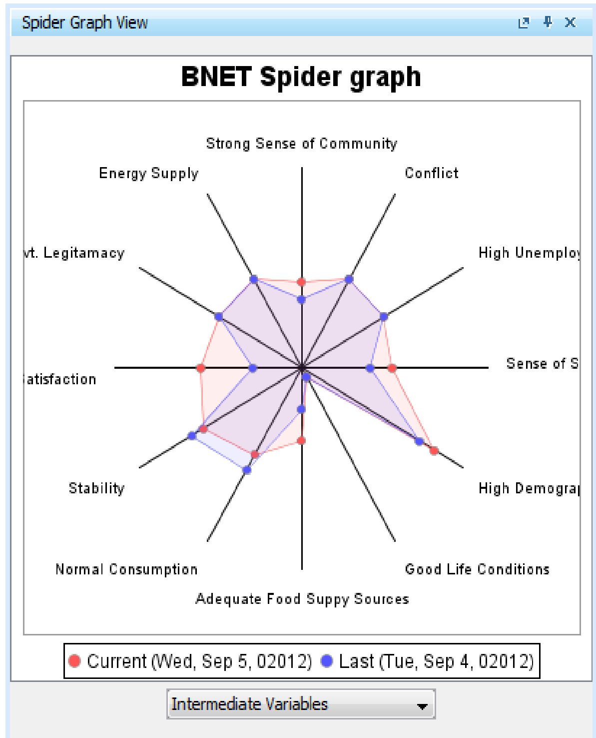

Figure 16: PMESII Model Spider Graph and Well-Being Gauge with Bayesian Drill-Down

In addition to modeling and reasoning about structural atmospheric variables, the system detects local Pattern of Life patterns and event anomalies. The system provides direct observability of these patterns, event drill-down, and comparing selected (or particular) days to a baseline that has been collected over time. An example chart is provided as **Error! Reference source not found.**.

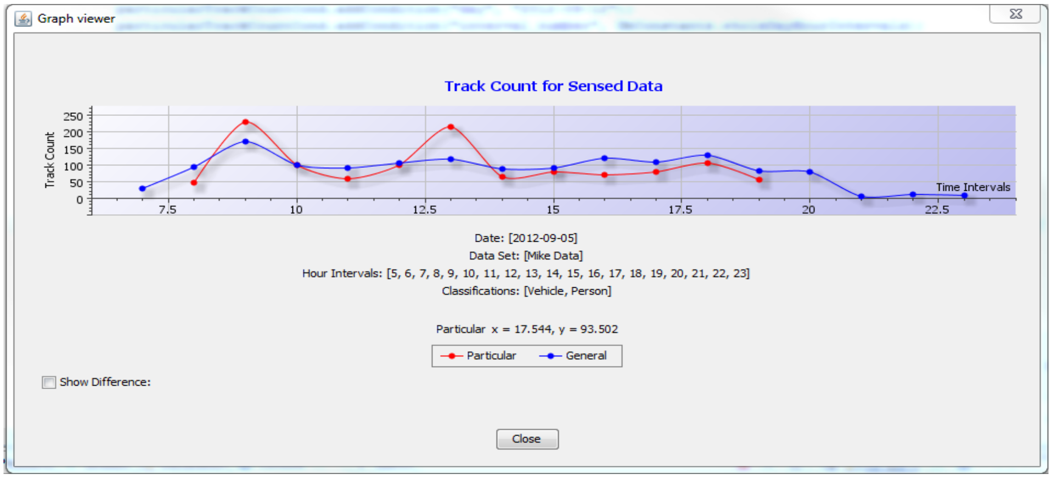

Figure 17: Pattern of Life chart examples

There are two primary implementation challenges in using in-situ sensors for SCSA. First is the number and cost of sensors to "cover" an area of interest. The second is the requirement for sensor placement. The original operational concept for using in-situ sensors was aimed at acquiring timely, local tactical SCSA in remote, often hostile, towns and villages, and potentially denied areas. Those cases would only require a relatively small number of sensors needed to cover a small number of key neighborhood contexts. Cooperative in-country human resources are also usually available for sensor placement. Scaling an in-situ implementation to a megacity is not necessarily as simple as a linear scaling by area when sparse neighborhoods are taken into account. Android platform sensors have also become relatively inexpensive. In-situ video and audio sensors are already common in some megacities and will become more common in the near future as a means to solve a range of management problems (McLaren, 2009). In those cases, data can be repurposed for SCSA assessment.

The work described here may support warfighters in using ground-level sensor-based data to assess a subset of social-cultural variables that are invisible to remote sensors or social media sources. This type of information is typically observed directly by tactical warfighters, but these observations do not have the ubiquity of sensors, and are subject to human concerns of availability, bias, interpretation, and reporting. While in-situ sensors were originally conceived for remote/hostile, sparse scaling, falling technology costs, and the growth of in-situ sensors for other purposes makes them of potential interest in megacities. Our existing enabling technology represents an impressive capability, but this progress is just the beginning of unlocking the true potential of a sensor-based approach for social-cultural assessment. There are many more sensors, processing capabilities, and social variables that warrant investigation and analysis.

Research Gap Summary

Based on our assessment of the urban social-cultural monitoring challenge and our own research results, we identified long term research gaps for understanding phase zero stability in dynamic urban environments:

Gap: Validation. The community should review social science model variables and their intended meaning, based on structured interviews with their creators and the warfighters who put them into practice. The community should promote sharing of a catalog that documents indicators relevant to stability and durability from a grounded social science theory perspective. This effort should encourage refinement and clarification of the concept of "atmospherics." It should also clarify the link to PMESII variables for social scientists, and identify a subset of "observable" indicators.

Gap: Cross-discipline teams. To avoid stovepiped development, funded efforts should be encouraged or even required to include cross-discipline experts to avoid the common issues surrounding the application of social-cultural theories to operational environments.

Gap: Operational needs and use cases. The Government and performers should document a set of common use cases that adequately represents the challenges of data collection and processing in operational settings. Models provide the capability to describe and reason about socio-cultural trends occurring in megacities, but the insight provided by the model must be aligned with the information requirements of the user community.

Gap: Sensor variable catalog. Efforts should catalog sensor variables that can serve as proxy variables for phenomena of interest.

Gap: Common challenge problems. Rather than expecting individual efforts to acquire data, common sets of data should be established for development and evaluation efforts

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Chapter Six, Building a Network-based Approach to National Security

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Abstract

The exponential expansion of information is rapidly changing the national security environment. Therefore, it is necessary to evolve our thinking and approach to national security, enabling cooperation amongst all elements of national power – from strategy to tactics – to influence and shape that changing environment. This means shifting our strategic view from linear and legacy approaches to network-based ones. To do that, there are changes that need to take place in information sharing and interagency coordination. Effective information sharing requires the dissemination of information, the granting of access to information, or both. The key elements of interagency cooperation are: 1) an interagency conference framework; 2) a base design or map of roles, responsibilities, and processes; and 3) the development of educational platforms. This paper uses the DOD counter threat finance (CTF) experience as a model to develop recommendations. However, the implementation of these recommendations requires cooperation across government, private, and academic sectors to begin developing the necessary relationships in the present that will enable civil societies to counter threat networks in the future.

Keywords

Counter threat finance, information sharing, interagency cooperation, trans-dimensional, illicit, industry, academia, Bitcoin, network, money laundering, framework, conference, education, professional development, enterprise, USNORTHCOM, webinar, national power

An Exponentially Expanding Problem Set

Providing scope in the modern era is becoming an increasingly difficult thing to do. The name of the concept of "Big Data" alone is misgiving, but that is the simple name given to a complex trans-dimensional universe of data that is generated at a rapidly expanding exponential rate every second of every day. For instance, it's estimated that four exabytes of unique information were created in 2008 (Fitch 2008). Just five years earlier in 2003, five exabytes were "equivalent to all words ever spoken by humans since the dawn of time" (Klinkenborg 2003). The growth of the populations that generate this data, as more and more human beings interact on a multitude of platforms and systems, requires the constant repair, expansion, or replacement of the infrastructures that support their daily activities, thus creating even more data. The volume, velocity, and variety of that data, as well as the mobility of its producers will present both challenges and opportunities to the structuring of conventional thought and the way we use it.

In just a few short years "[m]etropolitan regions will spill over multiple jurisdictions creating mega-regions. By 2030, there will be at least 40 bi-national and tri-national metro regions" (NIC 2012). In fact, over the next 15 years, the megacities of today will experience both the expansion and limits of their infrastructures, which will place increasing demands on their governments. They will be "limited by physical land constraints and burdened by vehicular congestion and costly infrastructural legacies, entrenched criminal networks and political gridlock, and deteriorating sanitation and health conditions" (NIC 2012). It's also important to note that a majority of data may lie within informal systems as only six out of 28 of the current biggest cities on Earth are in the developed world (Kotkin & Cox 2013). So how does one comprehend the amount or impact of the data generated by these increasing populations and its resulting universe of incomprehensible outcomes? The fact is, it's not easy, and it takes many hands – or in this case minds – to break it down, make sense of it, match data sets to other pieces in that vast universe of information, and give it meaning. Nobody can do it alone.

A Paradigm Shift for Strategy

Strategies must evolve to keep pace with the networked environment. This will require the USG to change at least two themes when it comes to developing and implementing strategy. First, it must find ways to facilitate interagency cooperation. Second, it must think about problems from an infrastructure point of view to better embrace a network-based approach.

All relationships are based on a certain amount of trust. A way of establishing that trust can be making a good faith effort of some fashion. For example, the Department of Defense (DOD) can easily further interagency cooperation by changing its approach to the development of its strategies, "de-militarizing" language where appropriate, and involving interagency partners early on in the process. This will assist to accurately develop mutually agreed upon goals and methods needed – especially in the area of civil support. These simple trust building steps are important, not just because they change a way of doing business, but because they begin to build the network necessary to navigate the globalized system and counter the threats found there, with a network-based approach.

One of the great legacy strategies from the Cold War is that of Containment. While the implementation of Containment Strategy had its detractors and took a long time to produce results, it did work. The success of it was based on the concerted efforts of all elements of national power in the confined space of a bi-polar, super power-centric world. The strategy was equal to the environment. Today's universe is stuffed with information, growing populations, and the infrastructures that support them. Making sense of it requires a paradigm shift from legacy strategies to those more capable of addressing this complex environment. That is where "network theory" may contribute. According to critical infrastructure expert Ted G. Lewis (2006), network theory is a way to model critical infrastructures. It is "more than theory; it is actually a practical way to model, analyze, and harden potential targets in nearly every critical infrastructure sector." Network theory can be applied to infrastructures, and then known techniques can be used to address the common denominators of problems associated with those networks. Thus, network theory has a strong potential application as a policy (and resulting strategy) to address the problems associated with today's globally networked environment.

Countering Threat Finance Strategy as a Model

A transaction is any combination of actors and technologies that facilitates the transfer of value from one party to another (Global Paymenst Handbook 2013). They can be formal, such as physically making a bank deposit, or they can be informal, such as bartering for items on Craigslist. Bad actors exploit these infrastructures to transfer value using a number of methods ranging from wire transfers and bulk cash smuggling, to trade-based money laundering (TBML), informal value transfer systems (IVTS), stored value cards, and virtual money such as bitcoin.[1] "Money laundering is not just a trade in itself but an irreplaceable mechanism of every other illicit trade. In a sense, money laundering is a mirror of the global underground economy (Naim 2005)." Each one of these methods adapts to an environment, whether it be to the global finance and banking system, the transportation system, or the Internet. The methods are realized either physically or virtually, and moved within or across systems in many concealed or alternative forms.

The current strategic look at illicit finance is agency or authority specific. Essentially, authority lines divide up the elements of national power that focus on threat networks. The Strategy to Combat Transnational Organized Crime (White House 2011), took a step toward leveraging these various authorities, even carving out a support niche for DOD involving the prioritization of work to enhance intelligence and information sharing. While the main effort of the strategy lies with three main elements, the Departments of State, Justice, and Treasury, DOD plays an important supporting role. It leverages its civil support mission through intelligence and information sharing. However, this support role also enhances DOD's homeland defense mission helping to shape the global or regional environment, thus reducing stresses associated with its homeland defense and security cooperation missions.

To support and shape environments, DOD has carefully constructed linking strategies for counternarcotics, which provides the authorities that DOD uses for its CTF activities. CTF is a term used by DOD to describe its support to the larger USG and international community goals of safeguarding the financial system against illicit use and combating other national security threats (Treasury 2013). It is defined by a DOD policy directive that states DOD "shall work with other USG departments and agencies and with partner nations to deny, disrupt, or defeat and degrade adversaries' ability to use global licit and illicit financial networks to negatively affect U.S. interests" (Defense 2012). Both DOD and its interagency partners use seemingly vague language to describe their roles with references such as "other national security threats" and "networks [that] negatively affect U.S. interests". However, the language is precision in that it recognizes the complexity of the environment, allowing for a network-based approach to tackle a problem set that no single entity can solve on its own.

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[1] Bitcoins are virtual in the sense that they exist solely in cyberspace, but they're expressly designed for the real world—specifically, any form of commerce where anonymity and untraceability are essential. Funds can be sent digitally across borders without physical transfer or anyone looking over your shoulder, and there are no fees or international exchange rates to worry about. For these reasons, bitcoins originally appealed mainly to anarcho-utopian types, plus drug dealers, gamblers and thieves. For more on the complexity of bitcoin see Cecil Adam's article, Cash Flop at: http://www.cityweekly.net/utah/article-17937-cash-flop.html.

All of these strategies link from a loose doctrinal point of view. They tie together across agencies and authorities, facilitating a view of the big picture, a possible foothold into deciphering those exponentially expanding exabytes of information, and an understanding of the developing massive infrastructures in which they move. This can be done without new or expanded authorities, but it must involve a paradigm shift from linear legacy approaches to those network centric techniques that address the illicit network problem set. Frameworks that support information sharing and interagency coordination are critical to that success.

A Way Forward: Information Sharing and Interagency Coordination

One of the five major recommendations of the 9/11 Commission Report was "unifying the many participants in the counterterrorism effort and their knowledge in a networked-based information sharing system that transcends traditional government boundaries" (9/11 2004). Information sharing is a concerted mantra of government talking points and leader engagement, especially in the post-9/11 era. However, it almost never gets the in-depth problem definition and participation that it deserves. For example, between the intelligence community and law enforcement there are two key concerns. From the intelligence community the concern is intelligence oversight with the restrictions it has to protect sources and methods. From law enforcement the concern is with discovery – the protection of the investigation, prosecution, and title 10 prohibitions on involvement with those activities. However, what really needs to be of focus to ensure that true information sharing comes to fruition is a communications framework that outlines the processes for protecting the information that needs to remain secure, while disseminating the information that needs to be shared. In its simplest terms, a communications framework requires one of two options from all interagency partners: 1) facilitating the dissemination of information by writing products to the lowest classification level possible, with a review or declassification process to get critical information to a usable format; or if that cannot be achieved, 2) there must be a mechanism to grant timely access to classified information. This framework must also facilitate quick response times, supported by a common understanding of the goal and the means to get there.

Since 9/11, interagency cooperation has also been a frequent point of needed improvement. However, there are things that support the relationship building and collaboration required to build a successful interagency construct. Some are priorities while others are not. For instance, many organizations have some form of a conference schedule where they interact with counterparts, share information, and sometimes conclude agreements. There's the annual G20 Summit, where leaders of the world's top economic powerhouses meet to promote global economic stability (G20 2013). Getting more USG oriented, the Drug Enforcement Administration holds an annual International Drug Enforcement Conference in a different country every year bringing together the counterdrug services of more than 120 countries to address the world's most pressing drug enforcement challenges (Filippov 2013). Even U.S. Special Operations Command's former Global Synchronization Conference (GSC) – the nursery for CTF – was a place where military, civilians, law enforcement, industry, and academia all came together to better understand illicit finance and develop ways to work with each other to counter it.

There are three key elements to improving CTF interagency cooperation so that it can shape the illicit finance environment and outpace the threats – serving as a model for the development of further networked-based approaches.

1. First, develop an interagency conference framework (such as the GSC) that develops decisions for leadership, gives agencies a strategic level event to plan their activities to, and uses individual conferences, committee meetings, working groups, and interagency activities to build agendas in support of strategic goals. This framework organizes agency events into an interagency network of key conferences that build to a single, culminating interagency conference. The key difference being that the ultimate goal of the interagency conference is to develop recommendations that are refined and then presented to an interagency executive council where leadership provides evaluation, adjustment, and decision. This in turn hones the interagency network and the focus of its activities.

2. Second, map out a base design of who does what and the processes to get things done so that there is a ready reference of information that lends to the improvement of CTF support organization and management. Snapshots of this map are embodied in the aforementioned DOD Directive for CTF Policy and the TOC Strategy, as each assigns roles and responsibilities. But there are relatively few comprehensive documents that map out the CTF or larger anti-illicit finance enterprise; and those that do often provide more misinformation than fact. Although specifically designed for U.S. Northern Command, an example of mapping the enterprise could be the "CTF Stakeholders and Entry Points" developed by the Joint Advanced Warfighting Program in (USNORTHCOM 2011). This map's purpose was to identify key nodes in the USG where U.S. Northern Command could initiate CTF support and/or place its very limited resources. The fact remains that it is one of the few comprehensive depictions of the anti-illicit finance enterprise. This product could well serve as the basis to further outline the interagency community's roles, responsibilities, and processes, thus improving the organization and management of CTF support to counter threat networks.

3. Third, develop educational platforms that not only facilitate this ready reference but also identify CTF experts to draw upon, and promote a network-based approach to countering threat finance. This effort must focus on building the core cadre among CTF professionals, vice contractor sourced development of training by non-specialist for mere familiarization. It must also serve the enterprise as a "one-stop shop" to educate leadership and anti-illicit finance personnel throughout the USG.

    a. Many such CTF professional training courses already exist. There is the DIA Threat Finance Course, which specifically develops the analytical talent for threat finance intelligence (TFI). There is the Joint Special Operations University (JSOU) CTF Course, which takes the step beyond intelligence analysis to a more specific operational support skill set. There are also courses applicable to countering threat finance in other veins of the elements of national power such as the Federal Law Enforcement Training Center's Criminal Investigator

Training Program, and various training courses in methodology, economics, and financial flows associated with the CIA's Sherman Kent School. Codifying the DIA and JSOU courses into core requirements, as well as courses from law enforcement and the intelligence community into elective courses for a program of CTF professional development, could advance interagency cooperation and thus information sharing, far beyond what it is now, and prepare a network-based approach for its critical future missions.

b. A further step forward in the area of professional development would be to leverage interagency relationships to better advertise these training opportunities, and facilitate the cross-training – in-residence or via mobile training teams – to improve fluency across the interagency lexicon and ensure unity of effort. An additional and more accessible approach would be to participate in and develop web-based training similar to that of the Naval Post Graduate School's (NPS) Terrorist Financing and State Response Self Study Course or the Association of Certified Anti-Money Laundering Specialist "webinar" offerings. Taking a giant leap even further could be CTF education along the lines of an accredited degree granting institution such as that of the distance learning offerings from the King's College of War Studies or the NPS Master's Degree Programs.

c. Providing for ready reference of CTF related materials is also a necessary resource to develop. A model to follow could be the Joint Electronic Library, which serves as a platform to gain access to guidance, training, the official DOD dictionary, and professional journals. This would support the on-going professional reading and reference for practitioners as well as support leadership and USG personnel education. Forms of this currently exist in pockets throughout the CTF and larger anti-illicit finance communities of interest, but none are accessible in a comprehensive or enterprise focused manner.

Finally, U.S. Special Operations Command (SOCOM) has been the "synchronizer" for CTF since the program's inception. In the course of developing and coordinating under this role, it has identified subject matter experts among the array of those who specialize in CTF from practitioners in government to those in industry, and academia. While not the sole resource, SOCOM can readily match demand signals with a supply of CTF Specialists to support customers, facilitating expertise, maintaining network integrity, and ensuring unity of effort in countering threat networks.

Networks present a complexity that is not fully understood and is difficult to explain because of its trans-dimensionality. Some will then consider the problem set "too-hard", making resulting strategies unequal to their environments and falling far short of national goals. That would be a mistake for the USG to make, significantly reducing its capability to shape and influence the global environment. Mega-regions are an example of the complex problem sets and demands that we will face in the future. Learning from that rising environment and applying network theory to address the complexities associated with it is an enormous investment in the present that can have exponentially positive impacts in the future. Since 9/11, many have promoted the concept that it is better to exchange business cards in the classroom rather than on the battlefield or at the crime scene. The best way to facilitate that is to get people together so that trust networks form. This is often done through conferences and educational fora. Establishing conference and education frameworks will develop the community trust necessary to facilitate information sharing and interagency cooperation. It will help to change the way we structure our thought about the volume, velocity, and variety of data. It will provide the basis for leveraging the strengths of all elements of national power, and building a network-based approach to national security.

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Chapter Seven, Evaluating Slum Severity from Remote Sensing Imagery

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Abstract

The application of remote sensing imagery techniques to extract indicators of megacity neighborhoods can be applied together with traditional sociocultural analysis by adding real depth to models with quantifiable metrics. Commercial and civil government imagery can and is being used to evaluate intra-urban differences in neighborhoods of megacities to reveal economic variation. After performing image classification, these indicators can be measured at the neighborhood or local level to generate a scale of severity. This paper argues that traditional sociocultural modeling can be augmented and supported by the underlying physical metrics available from high resolution imagery, and that scientists from both fields should work more closely to develop models explaining where pockets of the worst living conditions exist in megacities worldwide. Mission planners can then focus on these areas to anticipate future conflict or instability, and mitigate negative impacts on stressed populations.

Keywords

Remote sensing, megacities, neighborhood analysis, terrain modeling

Why remote sensing for megacities?

Megacities are thriving and constantly changing in terms of composition, shape, neighborhood characteristics, building materials, and quality of life. They can be viewed as singular organisms, but this unnaturally blinds us to the regional and neighborhood variation found within their boundaries. Economic zones, pockets of deprived housing, accessibility to transportation, and public service availability can vary markedly in different sections of a megacity[1]. This paper evaluates some of the capabilities of remote sensing imagery to help understand and segregate the severity of slums by neighborhood. Knowing where the areas of highest economic deprivation exist in a megacity helps answer Lieutenant General Flynn's call for understanding the environment - especially how that environment impacts operations and who is impacted.

Some inherent differences in data, methods, and approach have prevented the adoption of imagery-based techniques into the type of explanatory modeling often used to assess political instability through a sociocultural lens. There are differences in measuring accuracy, vastly different elemental datatypes, and variation in sampling units between both types of analysis that can help explain this lack of methodological integration. The hypothesis is that characteristics of slums derived from remote-

[1] A megacity is defined as an urban areal extent with $\geq$ 10 million residents.

ly sensed data can, in fact, allow us to make inferences about the human condition, and assumes that these characteristics can be scaled by severity as factors for instability models.

Accuracy considerations

Remotely sensed information is created from data generated without direct contact. That simple definition means that not only satellites and airborne sensors, but also the visual observations of human activities are all considered remote sensing platforms. The focus here will be on the traditional sources of remotely sensed data processed from satellite sensors, and not airborne or visual observation data. Sensor photogrammetry and the need for precise positioning and geolocation require explicit spatial, spectral and temporal accuracy in remotely sensed imagery. These accuracy measures are an inherent part of remote sensing science.

However, the same cannot be reported for human behavior and attitudes. The desire for human indicators that can be measured from imagery is the main driver behind quality-of-life and slum severity research (Stoler et al. 2012; Cowen & Jensen, 2001; Owen, 2012a). Decision-makers trying to anticipate human activity need accurate background on the physical landscape. To a certain extent, geo-referenced imagery can deliver. Indicators from neighborhoods in megacities can be directly measured from imagery sources. Those indicators can serve as surrogates for human deprivation or well-being in the neighborhood. It is known that vegetation (and conversely, the fraction of impervious land cover), road surfaces and accessibility, image texture (entropy), exposed soil content, and terrain characteristics (slope, curvature) vary significantly in wealthy versus poor settlements in parts of a megacity in the developing world (Owen, 2012a). But estimates about *individual* human behavior cannot be made from such measures. In other words, the researcher is cautioned to avoid the *ecological fallacy*, whereby the characteristics of the neighborhood are incorrectly ascribed to an individual living therein. This difference in focus between the *individual* and the *physical land area* should be exploited to better inform sociocultural modeling.

The unit of analysis – differential datatypes

The unit of analysis differs between sociocultural modeling that is focused on individuals and groups while imagery analysis often focuses on the physical village, town or region. In geospatial and imagery science, research has been devoted to the study of neighborhoods as the unit of analysis. The term ‘neighborhood’, just like the terms ‘urban’ and ‘rural’, are defined in various ways, and this impacts our ability to scientifically measure them (Weeks et al., 2007). Neighborhoods can be defined by their structural parameters such as similar housing or roads, from their ethnic composition in census statistics, from town planning maps that define property subdivisions, or historically from names given when a memorable event occurred and residents were spatially polarized over an issue such as reacting to a hazard (volcanic eruption, floodwaters, nuclear accident). Neighborhoods can also be named by voting precincts, or proximity to a feature (cliff-dwellers, *los basureros*[1] (Owen, 2012b)). To properly utilize imagery data for research on neighborhoods

[1] In Spanish, refers to those who live adjacent to and make their living from a landfill.

within megacities, the historical and spatial context must be understood before boundaries are ascribed to each unit of analysis.

The decision of where to draw neighborhood boundaries for analysis within a megacity is therefore a very important one, since it impacts any measures that can be taken from remotely sensed data. The modifiable areal unit problem, or MAUP, results when boundaries are not defined by the theme being analyzed (Openshaw, 1984). Almost all population demographics and cultural information is linked to regions defined by administrative boundaries that are not tied to specific sociocultural themes desired. The researcher should therefore question whether the political boundary is the best one for their analysis.

For sampling within a megacity, it is generally safe to ascribe boundaries to areas of similar housing if one lacks ancillary socioeconomic data, however, other clustering techniques can also be applied. One may argue that such clustering introduces bias when spatial or structural similarity self-selects for the sampling unit. The researcher must strive to explain the spatial unit of analysis, whether imagery-derived, or from ancillary political administrative boundaries. Geospatially-referenced imagery samples differ markedly from the sampling unit often used in sociocultural analysis. In sociocultural analysis, surveys and polls are conducted on individuals within a larger population to measure attitudes or sentiment. Thus, the different unit of analysis and different datatypes explain the challenge of fusing sociocultural with re-

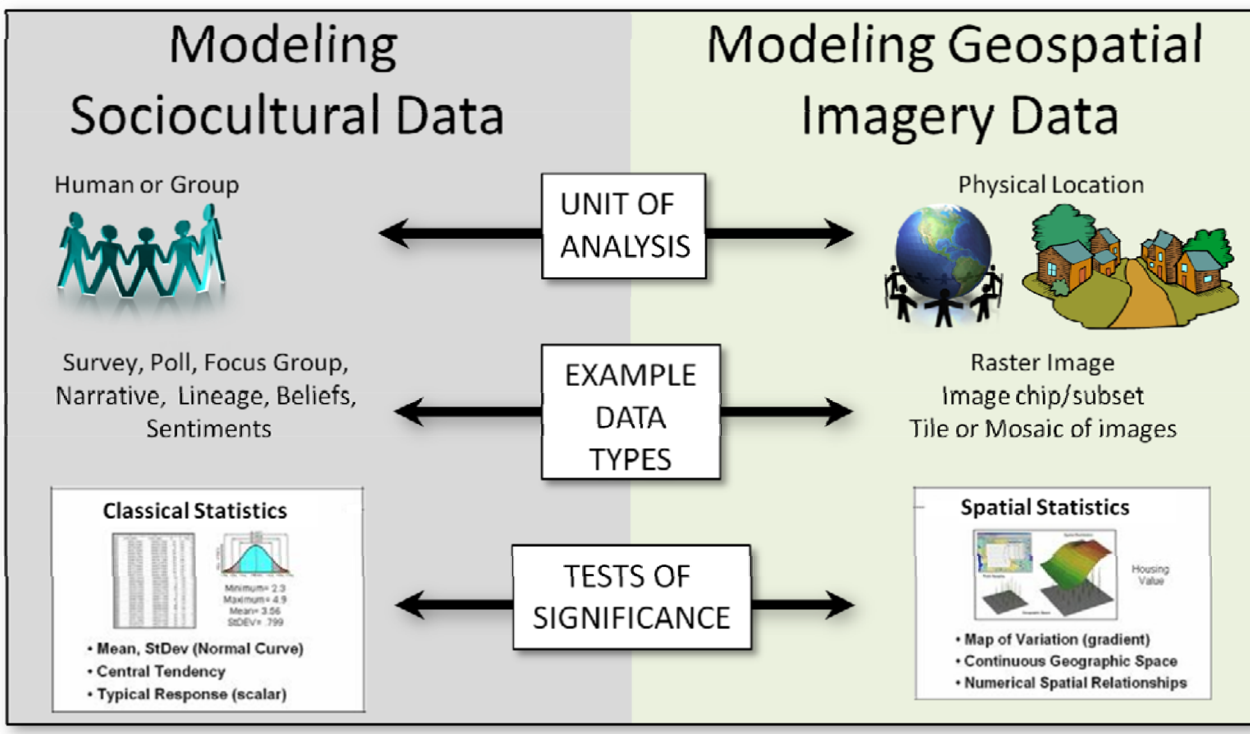

Figure 18: Sociocultural vs. Remote Sensing Modeling

mote sensing-based variables. Figure 8 depicts these differences.

City models

Geographic models with economic, social and structural emphases have been studied and applied to the shape and growth of cities for over a century, well before space-borne and airborne remote sensing platforms existed. They include Central Place Theory[1] (economic), Concentric Zone Model[2] (social), Multiple Nuclei Model[3] (social), and Roberts Settlement Framework[4] (structural). Many of these theories were applied to explain sectors of the city, or the relationship of the city center with outlying regions. Some theories focused on differences between individual neighborhoods, but historically, there was no ability to digitally mark boundaries or understand neighborhoods from the air. The original layout of cities in developing countries, often with roots in European Colonialism, may no longer be useful in explaining variability between neighborhoods because ethnic migration, zoning laws, and new road construction have caused drastic changes in their spatial arrangement. From a remote sensing lens of very high resolution satellite imagery, neighborhood variability might be explained now through the classification of building materials, building heights, favorable proximity to markets, or unfavorable proximity to man-made and natural hazards. These last items can be mapped as proxies for lower land values, lower living costs, and thus, where the urban poor normally reside in megacities.

Remote sensing-derived products and applications

Table 1 is a partial list of baseline civil or commercial remote sensing-derived imagery data, its purpose for use, and approximate ground sample distance (GSD, or pixel size). The GSD impacts the minimum size feature that can be extracted. Leachtenauer et al., (1997) suggest that to find a $15m^2$ dwelling would require pixel sizes to be a minimum of 1/5 to 1/3 of the structure size so that:

$p_i = (0.2 \text{ or } 0.33 \times a_f)$ where
p = pixel size in image ***i***
a = area of feature object (***f***) to be detected

Other image characteristics can impact the minimum size feature that can be extracted, such as the elongation of the feature and its smoothness of texture. In the example above, given a square dwelling and consistent texture, the minimum pixel size would be on the order of 6.7m, which is easily achievable with commercial imagery. This means the array of commercial very high resolution remote sensing data should be sufficient, but Landsat data would not.

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[1] Bradford & Kent, 1977, *Central Place Theory: The Cristaller Model*, in Human Geography – Theories and their application, Oxford University Press, Oxford.

[2] Park, Burgess & McKenzie, 1925, *The City*, University of Chicago Press, Chicago.

[3] Harris & Ullman, 1959, *The Nature of Cities*, in Mater & Kohn (Eds.) Readings in Urban Geography, University of Chicago Press, Chicago.

4 Roberts (1996), Landscapes of Settlement, Prehistory to the Present, Taylor & Francis, 1996

Table 3: Available Imagery Data

Baseline Need	Example Sensor Type	Purpose	Ground Sample Distance (GSD)
Land surface Characteristics, Land cover	MODIS	Weather patterns, Impervious surfaces, Vegetation coverage	250 – 500m
	Landsat		28.5m
Elevation and terrain geomorphology	ASTER GDEM2	Terrain slope, Elevation, Aspect, Surface curvature	15 m (VNIR) 30 m (SWIR) 90 m (TIR)
	SRTM		90m
Roads and road surface materials	WorldView-2	Transportation and accessibility	< 0.5m
	Quickbird		0.6m or 2.4m
Built-up areas	WorldView-2	Extent of anthropogenic structures	< 0.5m
	Quickbird		0.6 or 2.4m
	IKONOS		1m and 4m
	RADARSAT		50m
	TerraSAR-X		1m, 3m, 18m
	TanDEM-X		< 20m
Surface and subsurface hydrology	SRTM TRMM MODIS	Flood risk, soil moisture, water quality, precipitation	90m ~27km+/- 250-500m
Vegetation type	Landsat	Crop types and trends, crop yield vegetation health (phenology)	28.5m
	WorldView-2		< 0.5m
	AVHRR		~1km
Electrical Power Use	DMSP-OLS	Night time lights	1km

Though many of these products present a GSD that is too coarse to detect characteristics of individual city blocks or buildings, regional scale baseline needs can still be met. The fields of hydrological, atmospheric, and land cover modeling from remote sensing have well-documented methods of processing this data which provides the foundation to many useful human geography-related products. Normally the smallest GSD resolution data should be sought, especially for analysis at the neighborhood scale within megacities.

Features visible in Imagery

Automated methods to extract feature boundaries from imagery of megacities are challenging, but it is precisely such features that are needed to perform further analysis of socioeconomic characteristics of megacity neighborhoods. These features include roads, buildings, power plants, health facilities, schools, recreational areas, public service buildings and markets/bazaars. For example, the spectral information from very high resolution imagery can classify building materials by location. Certain building materials are indicative of wealth or poverty in an urban area (e.g., tile vs. adobe/mud), this can and has been used as an indicator of slums (Jain, 2007; Thomson & Hardin, 2000). Similarly, the physical composition of a road surface can also be derived from imagery, and this leads to a deeper understanding of accessibility to social services (paved roads provide greater accessibility) (Owen & Wong, 2012b). Man-made hazards such as landfills and factories can be markers to geolocate slums within a megacity because lower residential land values usually exist nearby, and some characteristics of those locations can be derived from imagery.

A basic classification of neighborhood slum severity using a range of indicators can explain the spatial variation in human needs by neighborhood that would be important during humanitarian, stability, or reconstruction operations. For example, Figure 9 displays a cut-score from the receiver operating characteristic curve for the indicator of *road entropy.* Road entropy is an image texture measure that is often higher in poor areas due to multiple materials found on roads, and this can be defined by neighborhood. In such a case, a score lower than the index means the neighborhood would be considered wealthy, and a score higher than the index means it would be classified as more impoverished. In a megacity, similar measures could be developed for a number of different indicators by neighborhood, to assign a slum severity index to each. This is a slightly different approach to the *inhabitability index* developed for the same problem set using imagery data from the megacity of Recife, Brazil (Filho & Sobreira, 2007). To be certain, a slum severity index would vary by climate or culture. For example, an index in a tropical, mountainous Latin American climate would have different indicators than an index in a desert biome in the African Sahel.

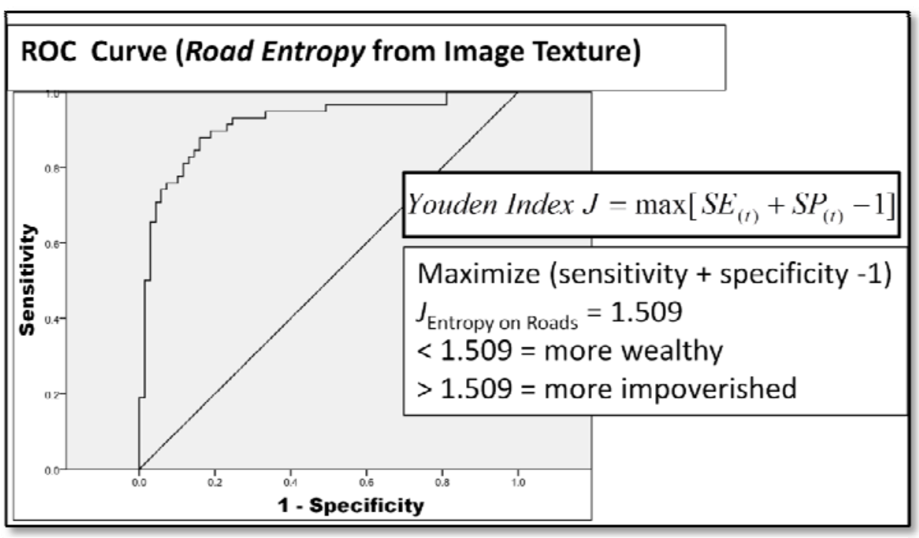

Figure 19: ROC Curve applicability to slum severity measures

What can remote sensing tell us about stability?

Remote sensing can describe the characteristics of place over time (using imagery time series), but it cannot explain the attitudes and beliefs of residents in a given image scene. Therefore remote sensing provides context and background upon which further modeling and analysis can be conducted. Questions that can be answered by remote sensing include:

- What is the weather (precipitation, land surface temperature, soil moisture) normally like in a given region during a particular time of year? (prediction, Bayesian estimation)
- What are the road surfaces, mean slope, and curvature to understand travel times in a region, or the relative accessibility to known human needs (markets, health facilities, schools)
- What types of crops are grown and what is their condition (phenology), and are they changing, expanding or shrinking?
- How congested are the roads, parking lots?
- What is the proximity to hazards, both man-made and natural (floodplains, steep slopes) to which residents are exposed?
- What is the building density, and thus, estimated population density?
- What is the quality of the soil and where are the impervious surfaces, and how does this impact runoff, flooding, erosion, or stream health?
- How much vegetation is normally found within residential areas, how is it distributed?
- What is the disaster risk for landslides and flooding (terrain and hydrologic modeling)?

Each of these questions can be answered from imagery, and their results can be described geospatially or temporally given the correct image product. Those results can then underlay, inform, or become input variables for neighborhood analysis in a megacity.

Merging social media analysis with remote sensing for megacity neighborhood study

Given that human opinions and attitudes cannot be modeled directly from imagery, a possibility is to fuse imagery-derived variables with social network analysis to evaluate whether landscape and settlement characteristics impact model outcome. Techniques have been developed that extract viewpoints from users of social media and place them by location[1]. Ambient geospatial information about an event or phenomenon (earthquake, for example) can temporally depict the center of mass or concern (re-tweets) for an event (Stefanidis, et al., 2011). Physical hazards, transportation corridors, weather patterns, terrain characteristics, and vegetative cover are examples of remote-sensing derived data that can now be modeled together with social media-derived ambient geospatial information for the first time in history. This fusion of remote sensing-derived proxy variables with geo-located social media information could provide new insight for understanding how social concerns vary by location.

Expanded use of remote sensing data for surveys and polling

In addition to synthesizing attitudes and viewpoints from social media with variables input from remotely sensed data, opportunities also exist to bind imagery-derived data with polls and surveys. The labor intensiveness, cost and risks associated with field-based research must be weighed by their benefits, but can be enhanced in the early stages by setting up sampling strategies that are informed by place, terrain, and neighborhood. Researchers can devise survey instruments structured by neighborhood type instead of by potentially meaningless administrative boundaries in a megacity, by using surrogate information about relative wealth and poverty to insert controls and remove potential bias in the survey instrument. Here again, the boundary problem surfaces when survey results are aggregated to a politically defined border. But this need not be the case. Structural imagery-based analysis of neighborhoods within megacities could ensure that comprehensive, systematic sampling strategies account for different economic zones or different terrain within a massive urban region. Field surveyors or pollsters who know they are likely to be delayed by inaccessible streets, teaming masses of densely-populated housing, or conversely, the elite who have no time to respond to survey questions could benefit from the knowledge gained using remote sensing-derived information when designing and implementing surveys. This represents another example where the fusion of imagery-derived information with sociocultural modeling may help explain some of the underlying factors that influence behavior differentially by neighborhood in megacity slums.

Conclusion

Although remote sensing cannot tell us whether a region or neighborhood is statistically likely to be politically or ideologically unstable (thereby increasing risk for armed conflict), the incorporation of variables populated from imagery sources into socio-cultural models is a new direction that could enhance the results by inserting spatially measurable observations. The outcome could include statistical and spatial correlation with physical landscape characteristics. It is highly advisable, therefore, that the capabilities of socio-cultural modelers and remote sensing image scientists blend with geospatial analysis to provide a new type of product – one that is better able to describe human behavior by linking people to the characteristics of the physical environment in which they live.

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[1] See MacEachren et. al (2011). Geo-Twitter Analytics: Applications in Crisis Management, In: 25th International Cartographic Conference, Paris. With bibliography at: http://www.geovista.psu.edu/publications/2011/MacEachren_ICC_2011.pdf

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Chapter Eight, Modeling the Discourse of Megacities: Assessing Remote Populations in the Non-Western Worlds

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Abstract

Megacities will play an outsized role in global politics and national stability over the coming decades with some estimates suggesting nearly three quarters of the world's inhabitants will be living in such urban environments by 2050. From water access to sanitation, flooding to healthcare, communications to transportation, megacities present a host of unique challenges, including the vast slum areas that surround or reside within them. These urban slums are characterized by a constant influx and outflow of migrant workers, high un- or under-employment, and complete lack of authoritative infrastructure. Developing world megacities often have high levels of tension between residents, the government, and urban elite as gentrification and development constantly erode or demolish housing and resources for the poor. Cities like Dhaka, Bangladesh or Lagos, Nigeria, have not historically been focal points of Western diplomacy and the lack of knowledge of their informational environments and cultural narratives poses unique challenges to analysis. While even urban slum areas are characterized by high cell phone penetration, the average non-elite citizen is not necessarily walking through the streets blogging, tweeting, or facebooking their daily lives. The massive and rapid influx of diverse cultures, the itinerant nature of large portions of the population, and lack of historic Western expertise in these regions complicate the construction of the cultural narratives and source catalogs at the core of OSINT analysis. In this state of constant flux and information scarcity, how does one effectively measure, monitor, and understand megacities?

Keywords

Social Media, Media Analysis, Megacities, Field Surveys

How Are Megacities Different?

To answer the question of how one assesses the populations of megacities, one must first begin by asking the question "just how are megacities different?" How is exploring the population of a megacity like Dhaka or Lagos any different from assessing that of a city like Moscow or Paris? What are the greatest similarities and differences between megacities and the more traditional large cities that Western OSINT has been monitoring for the better part of a century? At first glance, the rapid growth and constant influx of a highly heterogeneous population into megacities might suggest that the process of narrative construction, so critical to understanding and contextualizing media messaging and impact, may be much more complex in megacities. Most megacities are also in areas of the world that involve cultures and languages not as highly represented within the intelligence and military community and thus might present a more "foreign" analytic environment more difficult for analysts to immerse themselves in.

Another key difference would seem to lie in the limited knowledgebase of the information sources of these cities. Over the 75 years of formalized Western OSINT, rich catalogs have been compiled documenting every known white and grey information source in cities of interest. The OSINT community has focused on building and actively maintaining complex networks of resources to monitor activities and perceptions through public sources and has developed the deep cultural expertise necessary to interpret and translate those trends to place them into their respective narratives and policymaking needs. Yet, most of the new emerging megacities have not historically been locations of substantial interest to Western policymaking needs. The knowledge of the media system and cultural narratives of a city like Dhaka, especially its slum areas, pales compared with the vast expertise on Moscow assembled over many decades of intense focus. One might therefore argue that megacities present two critically unique challenges to population assessment: analytic complexity and information access.

Analytic Complexity in Megacities

Megacities present a highly unique challenge to analysts attempting to understand their cultural narratives and rhythms. Most apparent is the lack of depth among Western analysts in the geographic locales and cultures of many of the emerging megacities. Over nearly half a century of the Cold War American intelligence and military analysts devoted substantial financial and human resources to the monitoring and understanding of Russian society. To this day Russian remains one of the priority languages of the intelligence community and Russian represents the single most collected language by the OSINT community after English over the past quarter century. Contrast this with Bengali, the language of Dhaka, for which just over twelve hundred articles were monitored by the Foreign Broadcast Information Service (FBIS) over the entire period 1974 to 1996.

In addition to linguistic barriers, the new wave of megacities are emerging in geographic locations and cultures that are often comparatively more "foreign" to the Western-trained analysts assigned to understand them. While Russian society is different than American society with its own narratives and cultural history, there are sufficient similarities and shared heritage with other European nations that an analyst can at least largely make sense of it. The developing world where the new wave of megacities are emerging are often characterized by complex tribal, ethnic, linguistic, religious, familial, and societal affiliations and interconnections not as common in the Western world.

Complicating this is the rural-to-urban migration that feeds the enormous growth of megacities, leading to a highly diverse influx of cultures and societies that changes population composition faster than analysts can properly make sense of it. While other large cities like Moscow and Paris experience their own urbanization-driven growth, such expansion is still relatively homogenous and changes to their underlying population demographics occur far more slowly than megacities. Thus, the shear speed of megacities' growth and the cultural diversity of the rural population they bring together present an even greater challenge in that analysts must bring to bear expertise across a much wider and constantly growing set of cultures.

At the same time, the increasing role of non-state actors, increased subnational conflicts over the past quarter-century, and especially the rise of social media over the past decade, has effected a similar acceleration of change. These changes have also effectively removed geographic distance as a barrier to interaction. Today, people from across the globe catalog for the entire world their daily lives and innermost dreams and fears. Ideas, beliefs, and perspectives that formerly were geographically circumscribed to a specific social or cultural group are now available for the entire world to interact with. In essence, while megacities may be unique for the way in which they rapidly bring such diverse cultures together geographically, this process has actually already been underway in the virtual world through the rise of social media. If it ever was possible in the past to exhaustively map out the media system of a nation and all of its cultural narratives, record them in a book, and place it on a shelf for a decade before it needed updating, that time has long past.

From 1945 until 1974 the US OSINT community needed only issue its global catalog of radio and television broadcast stations ("Broadcasting Stations of the World") on an annual basis: such was the relatively slow rate of change of the media ecosystem in most nations. As the rise of cable and satellite television relaxed geographic constraints on information consumption in parallel with exponentially growth in the number of available channels, maintaining this global catalog became more difficult. Such a catalog today would be outdated nearly the second it was finished. With upwards of 600 new websites being created every minute, tens of thousands of new blogs launched every hour, and half a million new daily users joining Facebook each day, the media environment of the digital age is in a state of near-constant flux. This does not mean that we cannot measure the online media world; it means we must measure it far more rapidly while constantly reassessing its changing narratives. This is especially true as highly diverse and often "foreign" cultures intersect in fundamentally new ways.

Compared to traditional cities, megacities often grow faster and with an accelerated the rate of cultural assimilation and interaction. This requires that the interval at which megacities' communication ecology must be assessed be reduced considerably. In other words, the challenges presented by megacities to remote assessment are not that dissimilar from those of the rapidly changing online world. The historical approach of the intelligence community of hiring individuals with in-country expertise and then placing them in a cubicle across the Potomac for the rest of their career must give way to closer and more fluid integration to absorb this more rapid rate of change of the information lifecycle.

Information Environment Differences

In addition to greater analytic complexity caused by faster and more diverse growth, a more serious obstacle to assessing the populations of developing world megacities is caused by the relative scarcity and greater complexity of their information environment.

Assessing the entirety of the media environment in a nation, from secular to religious media, mainstream to social, broadcast to print, and understanding not only the production, but the demographic consumption of that media, requires a substantial and sustained investment over time that has not been made in the regions where many of the new megacities are emerging. In the areas where some investment has been made, it is often on the more popular mainstream media or on assessing the footprint of Western social media like Facebook and Twitter, while analyses of domestic social platforms like VKontake, and Weibo occur far less often.

In order to better understand the communication ecology of megacities, we will need to fuse multiple types of information including social media, mainstream media, field surveys, government records, remote imagery, and cellular records, as discussed in more detail below.

Social Media

In developing world megacities, social media use in particular is often highly skewed to a narrow slice of the urban elite and nearly non-existent in the slum areas we are often most eager to understand. A recent study of domestic Twitter output during the September 2013 Pakistan earthquake by the Digital Humanitarian Network on behalf of the United Nations Office for the Coordination of Humanitarian Affairs found that "none were actually informative or actionable."[1] The report further found that the "disaster-affected region is a remote area of south-western Pakistan with a very light social media footprint" and thus "there was practically no user-generated content directly relevant to needs and damage posted on Twitter… in stark contrast to our experience when we carried out a very similar operation following Typhoon Pablo in the Philippines." One of the core conclusions of the study was that "if there's little to no social media footprint in a disaster-affected area, then monitoring social media is of no use at all to anyone."

While this might seem obvious, it is important to note that many of the urban slum areas have similarly low social media penetration. Just 5% of the entire population of Bangladesh has access to the Internet and just 2% use Facebook, compared with 81% of Americans having Internet access and more than half of them using Facebook regularly. More importantly, 78% of those Bangladeshi Facebook users are male, largely between 18 and 34 years of age, meaning the social media ecosystem of Bangladesh is enormously skewed towards a narrow slice of its urban elites. While this suggests that social media may be less useful as a proxy of population beliefs within megacities in the developing world, Tokyo and Jakarta, the two largest megacities in the world, are both among the most active cities in the world in social media use, suggesting it may be more useful in the developed world. Building accurate neighborhood-scale maps of where land-based, wifi, and 2G, 3G, and 4G cellular networks are developed throughout the world will provide further understanding of the future of social media penetration.

[1] http://irevolution.net/2013/09/27/results-of-micromappers-pakistan-quake/

Mainstream Media

Despite low literacy rates, local community outlets often provide media services in slum areas, usually through localized low-powered radio broadcasts or grey literature in public spaces that are more difficult to access remotely. Mainstream media in the urban core is more easily accessible and presents few collection difficulties beyond those of other cities other than that media can be more fractionalized in megacities due to the density of different cultures. While tier one press functions the same as in other cities, megacities can have a larger prevalence of more localized media such as neighborhood outlets that serve specific communities, especially select social or cultural groups. The stronger role of religious, ethnic, and other social bonds in many of the areas where megacities are emerging also leads to specialized media, such as Islamic media in Bangladesh, which are a primary shaping influence among the uneducated poor and lower-middle class. Yet, overall, media appear to function in megacities in much the same way they do everywhere else across the world.

Field Surveys

Field surveys, especially face-to-face interviews, are the gold standard of population assessments. Whether face-to-face or via phone, field surveys are more difficult in megacities, especially the urban slum areas. While cellular phone ownership is extremely high in slum areas, they are used nearly exclusively for job and information seeking rather than for casual conversation or entertainment, with airtime minutes a precious commodity, making phone polling more difficult. Face-to-face field survey results become quickly obsolete as the demographics in an area change due to the high transient population, while high distrust in government and authority figures in slum areas can greatly reduce both response rates and accuracy of results.

On the plus side, developing world countries encouraging NGO participation, such as Bangladesh, are much more open to NGO and partner nation field surveys as well as sharing government records for phase zero operations. Ongoing research at ERDC is making it easier to combine multiple field surveys into a single socio-cultural data frame projected onto geographic coordinates.[1]

Government Records

While useful in the urban elite areas of megacities, governmental records provide poor to non-existent coverage of urban slum areas. Buildings are often erected without government approval or oversight and power, water, and sewer connections are frequently illegally tapped. Many areas do not even have regular government presence. In preparations for the World Cup, Brazilian government forces are taking control of some favelas that have not had standing police patrols for decades. Thus, governmental records of slums and their populations do not capture a comprehensive image of society. Instead, as utility companies increasingly fight back on illegal tapping, the detailed records they keep of the connections they locate and

[1] A component of the SMA/ERDC project "Megacities – RSI" is prototyping this research effort with implementation in the ASA(ALT) funded ERDC project "Phase Zero Assessment of Urban Security Threats".

disable can be used to trace the development of informal industry in these areas. In this way the lack of regular government presence in the slum areas of some megacities do provide some unique challenges to assessment, but not necessarily greater than that of the rural areas of other nations.

Remote Imaging

The application of remote imaging in megacities is significantly complicated by their exceptionally high population density. The five residential towers of South City in Kolkata, India for example together house more than seventeen hundred families, with a single building housing hundreds of housing units. While not necessarily different from other major cities, the greater reliance on high-density residential tower complexes makes assessment more difficult. However, as such complexes become increasingly popular throughout the world (7 of the 10 tallest buildings in the world are in Dubai despite it not yet reaching megacity proportions), this distinction will fade.

Please see Chapter Seven by Dr. Karen Owen for an in depth discussion on how high resolution remote imagery can better measure socio-cultural indicators in slums and other urban areas.

Cellular Data

Cellular phone data has increasingly become available for open academic research through so-called Cell Data Records (CDRs) that record the metadata of who calls whom, when and for how long. To preserve privacy, these records are wiped of identifying information and aggregated to a sufficiently large geographic region to make identification of individuals difficult. They also do not include any information about the content of the call, only the metadata recording that the call took place. A growing body of academic studies has demonstrated how such data can be used to explore the daily rhythms of a society, from estimating likely migration patterns in the aftermath of a natural disaster to mapping informal neighborhood networks. While at first it might seem counterintuitive to utilize cell phone data to map the urban flow of megacities, especially their slum areas, they are in fact one of the richest data sources on realtime population movement.

Phone records are particularly good at mapping the urban slum areas for which few other data sources, such as financial transaction data, exist. Populations in slum areas are often immigrants from rural areas who rarely have stable employment. Instead, they use their cellular phone to seek and receive jobs, much as a rickshaw driver uses his cart to constantly solicit and receive passengers. Phone penetration in slum areas is therefore extremely high, but few are modern smart phones and even fewer have large mobile data plans available for social media use. Yet, even though they are not significant sources of social media material, phone use in slum areas can still yield substantial information on societal patterns. Informal transportation networks in particular can easily be captured through the population-aggregated trail of cellular breadcrumbs, such as popular shortcuts and which alleys, paths and roadways are most commonly taken. Even more powerfully, such data can be used to map out the informal community structure, especially neighborhood boundaries, within a slum area, showing which communities interact most commonly within themselves, where they work, and how they get there.

Cellular patterns are perhaps the only information stream which is equally available in both elite and slum areas and which exhibits little difference in availability in megacities and ordinary cities. Yet, at their best, CDR records can show us only society's daily patterns and the deviations from those patterns that are a reaction to events or changes in beliefs, but not the context around them. They can show that the normally-bustling weekly market was empty or that everyone evacuated from a certain neighborhood at a certain hour, but cannot tell us why. In this way they are much like satellite imagery, but captured from the ground and thus unaffected by the residential density that may stymie overhead imagery.

Putting It All Together

The rapid pace of change, high cultural and linguistic diversity and perceived "foreignness" of the narrative environment of megacities complicate analysis, while the relative scarcity of the information environment and lack of deep expertise in their media systems makes collection difficult. Yet, these are also the defining characteristics of the online sphere in which all cities now reside and thus are not unique to megacities. Non-megacities may be more geographically homogenous with a lower physical influx of residents, but all cities today simultaneously exist in a rapidly growing and globally heterogeneous online sphere that mirrors all of the same challenges of megacities. The diversity of voices and cultures brought into close geographic proximity with such rapid speed in megacities are no different than the rapidly-shortening communicative distance among the world's cultures online. From this standpoint, the same approaches and methodologies being developed for understanding the rapidly changing and unfamiliar environment of social media have direct applicability to megacities.

From the standpoint of the available information environment, megacities similarly do not appear to be as dissimilar from traditional cities as has been portrayed. Social media use is extremely low in megacities in the developing world, but its use in developed world megacities is among the highest in the world. As cell phone infrastructure improves in the developing world, there will likely be quick transitions from low to high social media use by subpopulation within developing country megacities. Other than greater prevalence of local media, mainstream media operates very similarly to that of other cities. Field surveys and remote imaging are more difficult due to the extreme residential density and highly transitive population, while government records are often non-existent in slum areas. However, these are not significantly more dissimilar than in other cities. Cellular data provides even coverage of both elite and slum areas, but at the expense of context describing the underlying patterns.

Megacities in the developed world have very high densities of social media use, meaning social channels can be used to assess their citizenry in much the same way they are used in any other city in the world. Tokyo, which was one of the original focal cities of Western OSINT, has a rich and vibrant culture of social media use across a wide swath of the population. At the same time, the large influx of megacities in the developing world over the coming decade does present specific challenges in that social media may not be as widespread or as representative of the overall population in those cities.

Literacy rates are still relatively low in the developing world, which translates to higher reliance on broadcast media, especially in urban slum areas. Low-powered community radio, broadcasting with just enough signal to be heard by others in the immediate surrounds, address issues, news, and beliefs specific to the local community and can provide highly detailed "neighborhood" mappings of slum areas. While exceptionally rich sources of information, the output of these radio stations is insufficient to collect remotely and thus must be monitored locally, greatly increasing the cost. Outside of the slum areas, however, broadcast and print media function largely the same as they do in any other city, albeit often with a larger number of available channels, requiring greater resources to monitor them.

A key question in all megacities is how to best map the media environment, especially the demographics of its producers and consumers. While for developed world megacities like Tokyo, this environment is fairly well understood, far less is known about megacities like Dhaka or Lagos. However, outside of just a handful of countries, most nations have private industry in which companies develop, manufacture, and sell products to the domestic population. In order to promote their products, companies in most places of the world buy advertising to put their brand in front of potential customers. Anywhere advertising is bought and sold a rich ecosystem of market research, advertising, and media advisory firms develop that specialize in mapping out the local media environment, what media outlets are used in what areas and by what people, the demographics each reach, the transfer rate of messages across mediums, and in general how to reach any specific segment of the population. Even cities like Dhaka and Lagos have a burgeoning array of such companies that can readily provide statistics on which radio shows are most popular in a particular community, or how widespread Twitter usage is with a certain demographic.

Conclusion

Putting all of this together, megacities are found not to be exotic entities that will require enormous investment to understand, but rather familiar constructs to those we already focus on. In particular, social and mainstream media provide the same powerful open source signals in megacities that they have provided in other large cities over the past three quarters of a century. The largest difference appears to lie in the geographic location of most of the new megacities in the developing world. In essence the greatest challenge of megacities is the pivoting of attention to areas of the world not previously emphasized by the Western OSINT community, rather than of characteristics unique to megacities themselves.

Chapter Nine, How Semi-Automated Analysis of Satellite Imagery Can Provide Quick Turn-Around Answers to Large Scale Economic and Environmental Questions

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Abstract

Civil satellite imagery time-series, from such platforms as NASA's Moderate Resolution Imaging Spectroradiometer (MODIS) and USGS's Landsat, can provide key insights into environmental and economic conditions. Researchers use these datasets to monitor large-scale spatiotemporal Land Use / Land Cover (LULC) changes, e.g. the expansion and composition of urban areas, crop abundance and predicted yields, and the availability of natural resources. However, completing time series analysis with these inherently noisy datasets can be a laborious and intensive process, as analysis is complicated by variable imaging conditions, including sensor artifacts, cloud cover, and shadows. In this chapter, we describe the development of an ENVI/IDL-based Time-Series Toolkit (TSTK) to mitigate these challenges and greatly expedite the process of time-series exploitation.

Keywords

MODIS, NDVI, Agriculture, Time Series Analysis, Environmental Applications, Fast Fourier Transform, Harmonic Analysis of Time Series (HANTS), Savitzky-Golay Filter

Background and Introduction

U.S. interest in both the wars in Iraq and Afghanistan ranged not just in military action but also in capacity building, infrastructure repair, and job growth. This requires understanding Iraq and Afghanistan's economic and environmental status and evaluating agricultural and natural resources. This information can be especially critical given many areas with local dependence on agricultural capacity to sustain livelihoods. These countries also suffer from cyclical droughts and floods, which can lead to further instability. In support of the effort to monitor agricultural conditions and water resources, the U.S. Government (USG) began using processed NASA civil imagery to identify large scale changes in land cover. These data were utilized to determine the overall vigor of vegetation, water resource availability, and to attempt predictive analysis of impending food scarcity issues.

MODIS Imagery

In order to accomplish these tasks, the USG began employing NASA's Moderate Resolution Imaging Spectroradiometer (MODIS) imagery. MODIS sensors are onboard

NASA's Terra and Aqua platforms and each have 36 spectral bands. Additionally, MODIS imagery covers most of the world twice daily, including the USG regions of interest. MODIS imagery is usually available within hours of collection and has varying resolution, ranging from 250 meters to 1000 meters. The raw MODIS imagery is initially processed by the Global Agricultural Monitoring (GLAM) project, a collaborative project undertaken by the US Department of Agriculture's Foreign Agriculture Service, NASA, and the University of Maryland, to provide tailored MODIS Normalized Difference Vegetation Index (NDVI) data in 16-day composites. NDVI is an image band ratio that takes the difference between the reflectance of the near-infrared (NIR) and red bands divided by the sum of the NIR and red bands. In general, abundant vegetation is characterized by high NDVI values due to vegetation strongly reflecting in the NIR band and weakly in the red band. Water reservoir surface area can also be calculated from the composite NDVI product as water is assigned to a unique integer value (50). The NDVI product is processed to reduce cloud and atmospheric contamination and is provided in large area coverage GeoTIFF tiles. The tiles cover 71 regions around the world. In order to utilize the data, the USG further processes the NDVI to become usable analytic products.

Methodology

The Time-Series Toolkit (TSTK, Point of Contact – Sean Griffin) was developed internally at the National Geospatial-Intelligence Agency (NGA) as a plug-in for the ENVI/IDL image processing software (Exelis Visual Information Solutions, Inc.). The TSTK can be utilized for many different monitoring applications, including agriculture and water reservoirs. For agriculture, it can be used to monitor how vegetation changes over time and to develop a baseline for comparison, e.g. inter- and intra-seasonal vegetation growth. The tool also supports assessing the agricultural impact of natural disasters, such as drought or flooding. For water reservoirs, quantifying surface area through time provides a measurement of relative water levels.

The available NDVI data from GLAM ranges from 2000 to the present. Once the data is retrieved from GLAM, it requires further filtering to help eliminate bad data, snow cover, and other artifacts that may create anomalies in the dataset. The two filters used for this method include the Harmonic Analysis of Time Series (HANTS) and Savitzky-Golay (SavGol) filters. HANTS is a modified Fast Fourier Transform algorithm that screens and removes cloud contaminated observations and allows for temporal interpolation of the remaining observations to reconstruct gapless images at a prescribed time. The SavGol filter uses a method of linear least squares with a low-degree polynomial to fit equally spaced successive sub-sets of adjacent data points, example results are shown in Figure 10.

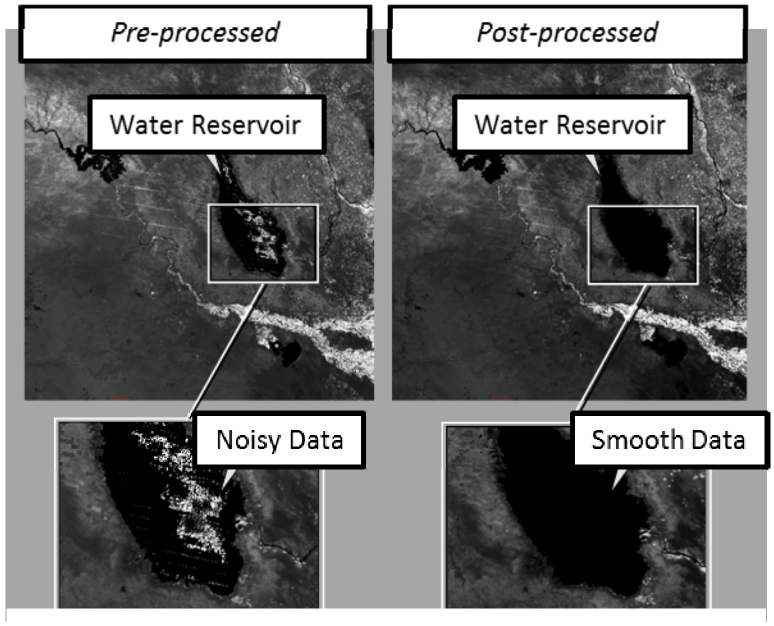

Figure 20: Example of smoothing noisy MODIS NDVI data values using the Savitsky-Golay Filter

Agricultural Application

The agricultural assessment methodology using TSTK is outlined below:

1) Create a layer stack of MODIS NDVI subsets based on sequential time periods and region of interest (ROI).

2) Using an ENVI Region of Interest (*.ROI) or ENVI Vector File (*.EVF) file, subset your layer stack to your area of interest.

3) Apply HANTS filter (typical application: interpolated with good data from 51 – 250 (eliminates water which has a value of 50), frequency of 0-2, fit tolerance of 60, and maximum iteration of 10).

    i) Further smooth the data with HANTS (requires a water mask)

    ii) Convert 8-bit integer values to original floating point NDVI values(i.e., 0.0 to 1.0)

4) Apply the SavGol filter for additional signal processing. This step is optional.

5) Identify potential crop of interest (e.g., wheat, barley, rice, cotton, etc.).

a) Determine ideal growing season of crop within the region of interest using a combination of signal interpretation and crop calendars. Best practices would also involve applying an analysis mask that would distinguish agricultural regions from forested, urban, desert and other non-agricultural regions. If more specific crop masks are available for certain crop types, those should be used in order to reduce the inclusion of non-crops of interest.

6) Identify peak NDVI.

a) After narrowing down the crop to the harvest season, the TSTK allows the user to determine the peak NDVI value during that time period. The user should attempt to narrow down specific peak NDVI dates for their time periods of interest and apply these to the baseline comparisons.

(i) Determine peak NDVI date during the ideal season (i.e., summer vs. winter crops) Use TSTK to develop difference products that either provide an absolute difference or percent change in NDVI.

7) Output difference products to assess change.

a) TSTK can develop GIS-ready NDVI analysis products that either compares the current year with the previous or with the 5-year and 10-year average for the date of interest.

b) The final product can be displayed in ArcMap and assigned a color legend using standardized layer files.

Examples of the output would include a classification map that shows the percent difference of the current crop NDVI from the 10-year average.

Water Reservoir Application

The water reservoir methodology is outlined below:

1) Create a layer stack of MODIS NDVI subsets based on sequential time periods and region of interest.

2) Using an ENVI Region of Interest (*.ROI) or ENVI Vector File (*.EVF) file, subset your layer stack to your reservoir of interest.

3) Visualize and apply user-defined SavGol filter parameters (typical is 5x5, Degree of Polynomial is 2). The SavGol filter in the TSTK was modified to not only remove noisy data values, but it converts the stretched 8-bit NDVI integer values to the original NDVI value range from 0 to 1, with water assigned to a value of zero and non-water assigned to values greater than zero.

4) Open the processed layer stack in the MODIS Water Monitor application (an integrated feature available in the TSTK):

a) Select your area of interest (see #2 above)

5) Modify the date range of interest (the default is to use the entire date range of the time-series dataset)

   a) There is an option to modify the sample dates from 16 days (as in one composite per data point) to 32 (2 composites/data point) or 48 (3 composites/data point). Modifying the sampling dates can be useful in eliminating areas that have consistently bad data throughout several 16 day composites.

6) Apply the contour fix that can often fill in bad data values that were not rectified during the initial smoothing process.

7) Use the MODIS Water Monitor to plot and visualize relative water levels for the reservoir of interest (this feature plots the water pixel counts within a reservoir over the date range of interest).

   a) Save out the plotted data to a comma separated value (.csv) file.

      i) Open the .csv file in TSTK and you have the option of fine tuning the smoothing process. The final exported .csv file from this process is your end data set (and you can display it as you see fit).

   b) Graph the results to compare current levels to the baseline.

      i) Data can be presented using a quartile analysis to allow seasonal comparison. This involves plotting the relative surface area as a function of time of year in comparison to quartiles from prior years. For example, the 2013 relative surface area plot would be compared to the minimum, quartiles (25%, 50%, 75%), and maximum for years 2007-2012. As shown in Figure 11, this can be used to identify when relative surface area is amongst the lowest seasonally over a given range of years.

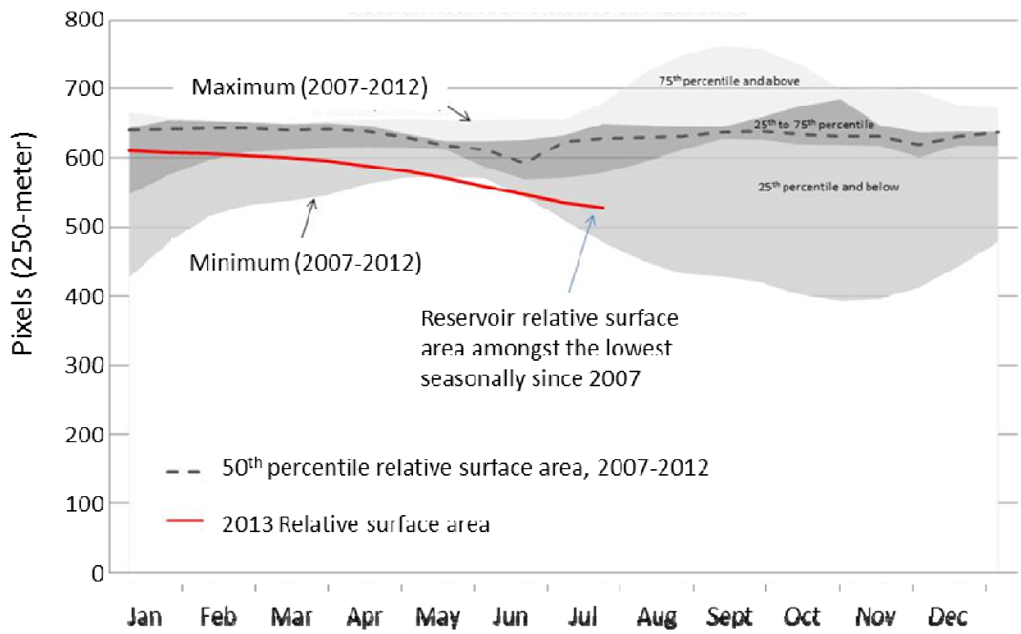

Figure 21: Example of monitoring reservoir relative surface area and comparing this to prior years. In this example the 2013 relative surface area is amongst the lowest seasonally since 2007. Relative surface area (as count of 250-m water pixels for reservoir) for 2013 is plotted as a function of time of year and compared to the minimum, quartiles (25%, 50%, 75%), and maximum

Conclusion

The Time-Series Toolkit can be very useful for expediting civil satellite imagery time-series analysis for environmental and economic applications. As discussed in this chapter, it can be utilized to assess vegetation and water reservoir changes, with direct implications for monitoring food security and the stability of a region. Potential improvements include expansion to other civil sensors and further automation of different processes.

Chapter Ten, UrbanSim: Using Social Simulation to Train for Stability Operations

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Abstract

As the United States reorients itself towards to a period of reduced military capacity and away from large-footprint military engagements, there is an imperative to keep commanders and decision-makers mentally sharp and prepared for the next 'hot spot.' One potential hot spot, *megacities*, presents a unique set of challenges due to their expansive, often interwoven ethnographic landscapes, and their overall lack of understanding by many western experts. Social simulation using agent-based models is one approach for furthering our understanding of distant societies and their security implications, and for preparing leaders to engage these populations if and when the need arises. Over the past ten years, the field of social simulation has become decidedly cross-discipline, including academics and practitioners from the fields of sociology, anthropology, psychology, artificial intelligence and engineering. This has led to an unparalleled advancement in social simulation theory and practice, and as new threats evolve to operate within dense but expansive urban environments, social simulation has a unique opportunity to shape our perspectives and develop knowledge that may otherwise be difficult to obtain.

This article presents a social simulation-based training application (UrbanSim) developed by the University of Southern California's Institute for Creative Technologies (USC-ICT) in partnership with the US Army's School for Command Preparation (SCP). UrbanSim has been in-use since 2009 to help Army commanders understand and train for missions in complex, uncertain environments. The discussion describes how the social simulation-based training application was designed to develop and hone commanders' skills for conducting missions in environs with multifaceted social, ethnic and political fabrics. We present a few considerations when attempting to recreate dense, rapidly growing population centers, and how the integration of real-world data into social simulation frameworks can add a level of realism and understanding not possible even a few years ago.

Keywords

Social simulation, mission command, POMDP, counterinsurgency training

Motivation

Back in 2006, the United States was decisively engaged in major operations in Iraq and Afghanistan. Though traditional offensive-defensive operations remained prevalent, the challenges of fighting against organized yet surreptitious insurgencies and factions drew widespread attention. Today, it is widely accepted that future military leaders will face similarly stressful and demanding situations that are, in many cases, not covered by standard tactics and doctrine (Smith, 2005). These operations, which combine both lethal and non-lethal aspects of warfare, have been referred to as "armed social work," in which military forces attempt to "redress basic social and political problems while being shot at" (Kilcullen, 2006). The overarching challenge is to develop leaders who possess adaptive expertise and function effectively in complex environments, and to prepare them for novel situations unlike any they may have experienced in the past.

The School for Command Preparation (SCP) at Ft. Leavenworth is the primary Army institution for preparing newly-selected Battalion Commanders for all types of missions, including those centered on protecting and empowering indigenous populations who may be experiencing national security threats of their own. The school has an imperative to ensure their curriculum is updated with topics and material that best positions commanders for success once downrange. To address this challenge back in 2009, USC-ICT, in partnership with SCP, Army Research Laboratory (Human Research and Engineering Directorate and the Simulation and Training Technology Center), and Army Research Institute, developed an instructional software suite for military commanders and their staffs to practice directing and coordinating operations with a "stability-focused" component. The UrbanSim Learning Package (or UrbanSim for short) focuses predominantly, but not exclusively, on military operations in support of the local citizenry and government that take place after primary offensive and defensive efforts have concluded. Applying the principles from Guided Experiential Learning (GEL) (Clark, 2004), UrbanSim was designed, developed, and deployed with a strong pedagogical focus. The resulting learning objectives called for a complex, dynamic, yet highly realistic simulated environment, which brought about the need to employ agent-based research technologies and transition them to software that would eventually be used in a classroom setting.

Mission Command & UrbanSim

The foundations for commanding in the Army are framed around the precepts of mission command (MC): Understand, Visualize, Describe, Direct, Lead and Assess. A seminal precept of MC requires the commander to blend the art of command and the science of control, focusing on the human dimension of military operations as opposed to technological solutions. A toolkit of commander competencies helps to feed core fundamentals, including MC domain knowledge, communication, decision-making, adaptability, self-awareness and self-assessment. These competencies cannot be learned solely out of a book or as a set of rules. Instead they require practical, tacit skills which typically are developed through experience, time, and with the help of feedback from mentors, superiors, peers and subordinates.

The UrbanSim training package specifically targets the need for practicing these skills and techniques. The application targets trainees' abilities to maintain situational awareness, anticipate second and third order effects of actions and adapt their strategies in the face of difficult situations. It allows commanders and their staffs to develop skills in executing the "art of mission command" in counter-insurgency (COIN) or stability operations environments. The application includes two components: (1) a self-paced Primer; and (2) a computer game-based practice environment;. The training exercise typically takes one full day to execute. It may either be conducted individually in a classroom setting with a lead instructor (as is done at SCP), or in a Staff Exercise with different players assuming the roles of a Battalion Staff (BN CDR, S2, S3).

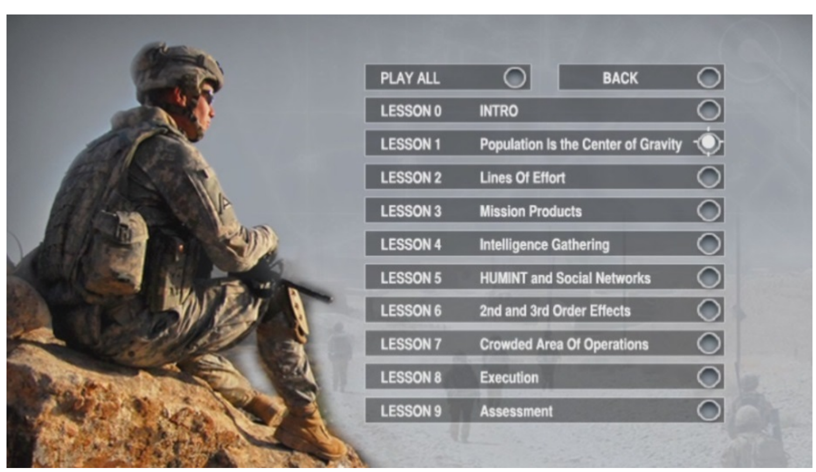
UrbanSim adheres to the GEL model by providing learners with a complete cognitive foundation required to conduct complex, dynamic operations ranging from high OPTEMPO, highly kinetic and security-focused, to lower-profile, governance or development-focused missions. The terminal learning objectives (TLOs) of the experience include:

1. Achieve and maintain situational awareness and understanding in a complex environment
2. Balance offense, defense and stability. Understand the role of intelligence and reconnaissance security / raids
3. Anticipate 2nd/3rd order effects of decisions; tactical effects with strategic consequences
4. Reinforce doctrinal principles of “Shape, Clear, Hold, Build”

These TLOs are exercised through various stages in the application, discussed in detail below. The enabling learning objectives (ELOs) are core MC topics that, when exercised at various phases of the game, help satisfy the TLOs. ELOs for UrbanSim include:

1. *Mission Overview* – understanding and interpreting higher-headquarters (HQ) intent; higher-HQ lines of effort (LOEs); and higher-HQ information requirements (CCIR)
2. *Mission Analysis* – understanding the landscape in the area of operations (AO) (e.g. political, economic and military networks, key individuals, organizations and groups)
3. *Mission Plan* – being able to author a tractable, realistic commanders intent, formulating and monitoring LOEs, CCIRs and measures of effectiveness (MOE)
4. *Mission Execution* – directing action of subordinate units in support of a desired end state
5. *Mission Assessment* – being able to self-assess performance along the LOEs and MOEs over time

The UrbanSim application has been used to train Soldiers in a variety of institutional settings to include SCP’s Tactical Commanders Development Program (TCDP); various Captains’ Career Courses; the Engineer Basic Officer Leadership Course; and the AMEDD Senior Leaders Course at Joint Base San Antonio. UrbanSim has been used successfully to stimulate battalion-level, battle staff exercises and to stimulate training for Company Intel Support Teams (CoIST) for Active and National Guard units at Ft. Hood, the Joint Maneuver Training Center (JMTC), and the California Na-



tional Guard. The training package was transitioned from the R&D community to the Army Games for Training (AGFT) Program in November 2011 and is available for distribution Army-wide via the Army's MilGaming web portal. UrbanSim also transitioned to the Army Low-Overhead Training Toolkit (ALOTT) Program in December 2011 and was fielded at Joint Base Lewis/McChord in June 2012 as part of the ALOTT New Equipment Training (NET) program.

The Primer

The first component of the experience, the UrbanSim Primer, provides the requisite conceptual and task knowledge required for the learner to lead a full-scale stability operation, from analyzing background information via target folders and intelligence briefings, to coordinating the actions that are carried out in support of achieving a desired end state. Taking the form of an interactive tutorial, the UrbanSim Primer is divided into nine lessons, each of which contain a narrative, interview segments from former Commanders, and assorted practice exercises as a means of demonstrating specific tasks to the learner. Taking approximately one to two hours to complete, the self-paced Primer prepares the learner for the second application, the more complex UrbanSim Practice Environment.

Practice Environment

The UrbanSim Practice Environment is a game-based tool that allows a learner to *plan, prepare, execute*, and *assess* a full stability operation. Similar to a turn-based strategy game (such as Civilization or Age of Empires), the learner directs subordinate units in the game to take action with and against agents (i.e. non-player characters, NPCs) in a virtual environment, and attempts to successfully complete a mission using the products/strategies learned in the UrbanSim Primer and in the classroom. Actions in the game are taken against key individuals, groups, and structures in an area of operation (AOR) with the intent of reaching the desired end state. Each turn-cycle in the game represents one day in simulation time, though actions can take multiple turns (i.e., days), and can be interrupted if conditions in the world do not allow the action to complete (e.g., money runs out to construct a school). Upon completion of a scenario, the learner is brought to a debrief phase where a summary of the mission is presented for the learner to evaluate their progress.

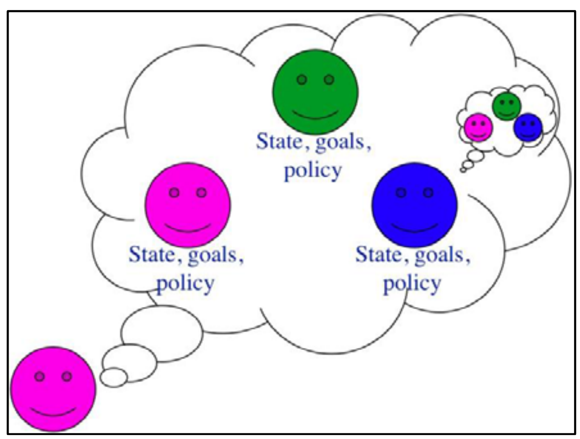
The game is driven by an underlying socio-cultural behavior model, coupled with a novel story engine that injects events and situations based on real-world experiences of former commanders. It also includes an intelligent tutoring system, which provides guidance to trainees during execution, as well as after action review capabilities.

The fundamental scoring mechanism of the game (i.e., how well the player does) is via the LOEs. There are six primary LOEs: Civil Security, Governance, Host Nation Security Forces (HNSF), Essential Services, Information Operations and Economics. Every action in the game has associated effects, both first and second-order, on one or more lines of effort. The value of the LOEs changes over the course of the game and at the end of the scenario are summarized for the player to see where their focus areas were (security, governing, developing), and whether they were aligned their desired end state. These LOEs, as well as all other secondary scoring values in the game (MOEs, CCIRs, etc), are determined by the underlying behavior model, described below.

UrbanSim's Social Model

The technical challenge of any game or simulation AI is that it must be both expressive but application friendly. Having a multi-tiered, self-organized and self-steering behavior system may in theory be realistic and desirable, but can quickly become intractable either in terms of performance or usability. Therefore one must carefully determine what the requirements are for any behavior system driving an underlying experience. For UrbanSim, this meant balancing expressivity and realism of the model with authorability of scenarios. To accomplish this, UrbanSim uses two separate but coupled AI technologies: PsychSim and the Story Engine. The integration of these technologies is via UrbanSim's system architecture, which follows a data-driven distribution model where AI components work together in a synchronous cycle. Each cycle begins when a learner specifies a set of actions to be executed by subordinate units for the given turn. These actions are then sent to an intelligent tutoring system for evaluation, which may initiate a question-answer tutoring dialogue with the learner. Once this dialogue is complete, the learner commits the actions and the simulation cycle is executed and repeated.

PsychSim



PsychSim is a multi-agent system developed by the University of Southern California (USC) that models beliefs about others to affect behavior of simulation entities. It is a framework for social modeling and simulation that has been used in a range of domains from analysis and planning to basic research on human behavior (Wang et al, 2012). In UrbanSim, entities are modeled using PsychSim and can represent both key individuals and aggregate-level features such as organizations, tribes, geographic regions or structures. The decision to aggregate was due to performance and the objectives of the trainer. UrbanSim is not a mission rehearsal tool, nor was it needed to include an accurate, validated social simulation. Instead, it is intended to teach critical thinking skills in commanders in environs that are representative of where they might eventually deploy. Though in some cases this may require a highly-detailed, realistic model down to the individual level, for the purposes of this trainer that requirement was never specified.

The PsychSim architecture is rooted in the Theory of Mind (ToM) principle. ToM is the ability to attribute [mental] states to oneself and others, and to understand that others have beliefs, desires and intentions that are different from one's own (Premack, 1978). In PsychSim this refers to agents that have subjective perspectives on others, and are able to potentially predicts others' actions/reactions, but also be able choose actions for themselves that will change the beliefs of others. Agents also have the ability to communicate, distort and hide information to influence others. In addition to ToM, decision-theoretic reasoning plays a pivotal part in PsychSim. This reasoning states that agents are free to pursue their own goals based on their values and beliefs. Often agents are presented with conflicting goals, or choices that must be made under uncertainty. In both cases, the agents will weigh the tradeoffs and make the best decision given the situation.

To do so, each agent generates its beliefs and behavior by solving a partially observable Markov decision process (POMDP). A POMDP consists of *state*, *actions*, *transition*, *observations*, and *reward*. The *state* of a POMDP in UrbanSim represents various features of the different entities (e.g., a structure's capacity, a group's military power, a person's political support), each a real-valued number from -1 to 1 (e.g., 1 means that the structure is functioning at 100% of capacity). The *actions* are the choices available to each agent (e.g., repair a structure vs. patrol a neighborhood), and the *transition* represents the effects of these different choices on the state. The *observations* capture the probability that certain states and actions are hidden from certain agents. The *reward* function represents what each agent seeks to achieve in the world (e.g., maximizing its own security, minimizing an enemy's military power).

Given a set of such POMDP models for the entities in the scenario, each corresponding PsychSim agent can use standard algorithms to compute its best course of action (Kaelbling, 1998). These algorithms operate by projecting the effects of candidate actions into the future, aggregating the reward resulting from those effects (as well as the effects of the anticipated responses by the other entities), and selecting the action with the highest expected reward.

In UrbanSim, the POMDP models of the underlying 'society' were created by non-technical subject-matter experts (SMEs) specializing in Iraqi and Afghan cultures. The baseline UrbanSim scenario, al 'Hamra, contains 92 non-player agents. This decomposes to over 1400 features and another 4700 possible actions. This quickly grows exponentially to almost 450,000 possible effects of actions. In any given turn, there are approximately 1000 different actions that the player can choose from, and 1100 possible responses for the agents.

One of the core features of PsychSim, and key to several of the learning objectives of the game, is the ability to generate causality chains of actors to capture both intended and unintended effects of agent actions. Many AIs in games and simulations cover *who, what, where* and *when* quite well. However the *why* (which elicits causality) has proven allusive due to the complexity of modeling human cognitive function in the minds of non-player characters. For entertainment game AI this rarely poses a problem. NPCs are often tactical in their behavior and do not require elaborate decision-making capability to execute actions like selecting their weapon, moving to contact, and even basic formation control. However for social simulation-based training applications, agents represent individuals and groups in a society with myriad beliefs, desires and intentions that must work together to produce coordinated, plausible action. Moreover, these actions must have meaningful effects that can be described to the user in a way that adds training value. In UrbanSim, this is accomplished through causality chains. Causality chains help establish concrete linkages between an agent's actions and their effects, and if the linkages extend multiple turns and are part of a fully connected societal graph, it allows us to address issues related to first-order, second-order and third-order effects.

Story Engine

Even with a tight control over authoring in terms of the available actions to PsychSim agents and their goal structure, the scale and scope quickly becomes difficult to manage. Though agents were taking actions that were plausible and contributed towards the pedagogical experience of the application, there were specific instances that project SMEs (former commanders) wanted to highlight to students as they played through the experience. This was difficult to force with a complex multi-agent system, and eventually led to the development of the Story Engine. The Story Engine was specifically designed for instructors and SMEs to incorporate real-world events and situations in the game. These events could be strung together to form stories that would play out over multiple turns.

The Story Engine uses as input variable states from PsychSim agents. The figure below presents an example where PsychSim agents took action to kill an Iraqi police officer. The event checks for when this condition occurs and then launches a storyline that involves conducting an investigation and working alongside the police chief to determine what happened. These events were authored to always occur, regardless of what action(s) the users or agents in the game take. The Story Engine is intended to convey key teaching points related to the learning objectives of the game.

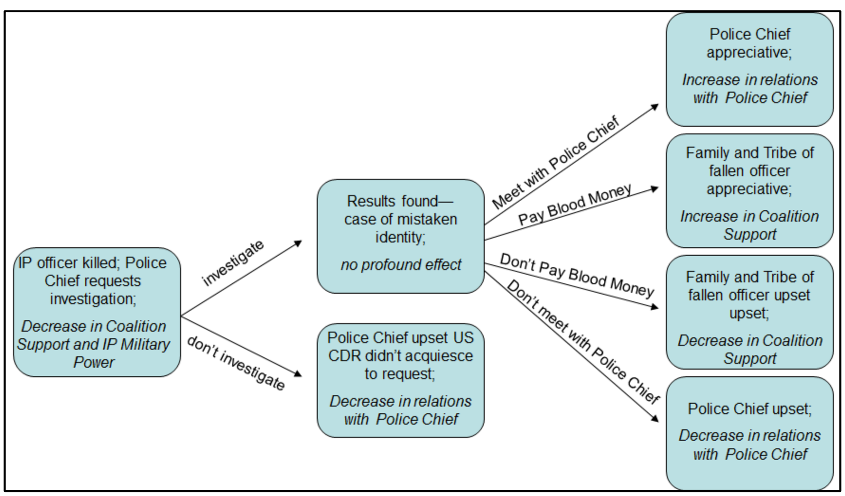


Figure 22: PsychSim Example

The use of dual AI technologies to drive UrbanSim has allowed scenario authors and instructors to tailor the experience for certain audience types. In cases where UrbanSim was used to train operational commanders during Staff Exercises, the heavy reliance on story events derived from similar real-world situations they might encounter was important in helping them and their staff prepare for conditions downrange. In cases where classroom instructors were simply covering the basics of MC with no specific operation or region in-mind, the diversity and richness of the multi-agent system was sufficient for students to gain an understanding of the complexities of the environments in which they may find themselves in one day.

Way Ahead

The strategic trajectory of the United States in terms of military engagements remains uncertain. It will obviously be influenced by geopolitical currents that we may or may not have influence over. TRADOC contends that the strategic environment will be "characterized by multiple actors, adaptive threats, chaotic conditions, and advanced-technology-enabled actors seeking to dominate the information environment. The Army must be operationally adaptive to defeat these complex challenges and adversaries operating within this environment" (Operational Environments to 2028, 2012). The National Intelligence Council outlines four potential worlds in 2030, influenced by 'megatrends:' individual empowerment; the diffusion of power; demographic patterns dividing the world into zones of population growth and others with stable or even declining populations; and a food/water/energy nexus that will lead to increasing competition for these commodities in places (Global Trends 2030, 2013).

1. "Stalled Engines" (a worst case scenario in which the United States draws inward, globalization stalls, and the risks of interstate conflict increase);
2. "Fusion" (the most plausible best-case scenario in which the United States and China collaborate on a number of issues leading to broader global cooperation);
3. "Genie-Out-of-the-Bottle" (inequalities within and between nations explode and the United States no longer manages world order); and,
4. "Nonstate World" (driven by new technologies, nonstate actors surpass states in confronting global challenges).

As Metz points out in the Strategic Landpower Task Force Report (2013), the most likely opponents of the US military are hybrid compositions of militaries and non-military entities, or 'evolved irregular threats' (Flynn, 2011). They will be highly complex, adapt rapidly, rely on asymmetric methods, and often operate in congested urban areas.

As training and technology continue to evolve alongside emerging threats from this futurescape, one important capability is being able to accurately model the social environments in which we may find ourselves. Though social simulation has morphed significantly since the days of the Von Neumann machine and Conway's Game of Life, investment must continue from a cross-section of disciplines (sociology, psychology, anthropology, computer science) to make social simulations a mainstay in future training solutions. Additionally, with the influx of big data from all corners of the globe via social media, there is a unique opportunity to incorporate it into our modeling approaches. For example, combining data mining with social media analysis techniques, we could adjust non-player agents to make choices based on specific locations: Dhaka and Cairo might have very different responses probabilities to the same situation. Not only has social media been shown to instrument change in the real world (Casilli & Tubaro, 2012), it provides the social simulation community with a valid and useful tool for developing and tuning their models. Research in this space remains scant, though as this data becomes more available and researchers understand its utility (and limitations), we can expect it to be a core foundation of social simulations in the future.

FASTEST GROWING MEGACITIES IN THE WORLD
(Urban Areas with more than 10 million residents)

Rank	Geography	Urban Area	Population Estimate	GROWTH (Decade)
1	Pakistan	Karachi	20,877,000	80.5%
2	China	Shenzhen	12,506,000	56.1%
3	Nigeria	Lagos	12,090,000	48.2%
4	China	Beijing, BJ	18,241,000	47.6%
5	Thailand	Bangkok	14,544,000	45.2%
6	Bangladesh	Dhaka	14,399,000	45.2%
7	China	Guangzhou-Foshan	17,681,000	43.0%
8	China	Shanghai	21,766,000	40.1%
9	India	Delhi	22,826,000	39.2%
10	Indonesia	Jakarta	26,746,000	34.6%

Figure 23: Top Ten Fastest Growing Megacities

As highlighted in (Kotkin & Cox, 2013), of the top 10 fastest-growing megacities in the world, all are either in Asia or Africa. 10-year growth in these areas is between 35 and 81%, yet our understanding of these regions remains limited. Obvious cultural and social differences make them unique to study, and combine this with complex and opaque political and economic structures, there is a need to find alternative approaches to developing our understanding of these locales. One approach involves using data mining and scrubbing techniques to help a cross-disciplinary team of anthropologists, demographers, social scientists and engineers develop models of populations residing in these areas.

For UrbanSim, work is underway to develop a new set of models and scenarios based on TRADOC's Common Training Scenarios (CTS) framework. The CTS is an expansive set of use cases that cover a variety of operation types from major combat to stability to disaster relief. At its core, CTS attempts to be both broad and deep in its coverage of potentialities. USC-ICT is working alongside social scientists, data miners and military SMEs to develop a stability-focused scenario with a strong non-state and coalition focus. One difference in the design approach from previous scenarios will be the reliance on social media feeds from the area of interest – in this case Georgia, Armenia, Azerbaijan, Turkey (GAAT) – to seed the modeling of the underlying behavior model. The scenario is scheduled for release in mid-2014.

Acknowledgments

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