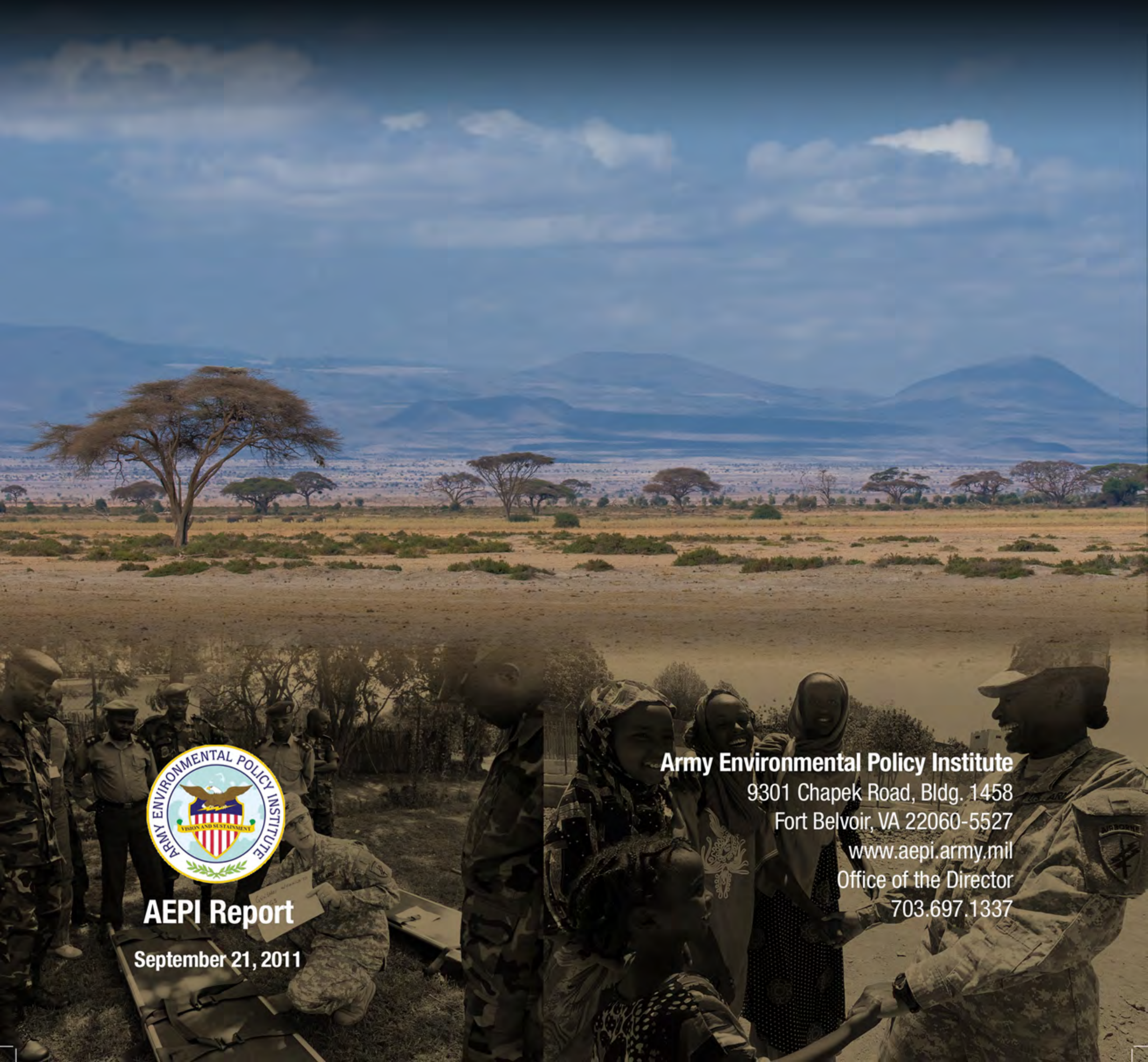
ENVIRONMENTAL CHANGE AND FRAGILE STATES

Early Warning Needs, Opportunities, & Intervention



AEPI Report

September 21, 2011

Army Environmental Policy Institute
9301 Chapek Road, Bldg. 1458
Fort Belvoir, VA 22060-5527
www.aepi.army.mil
Office of the Director
703.697.1337

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave blank)*

2. REPORT DATE
September 21, 2011

3. REPORT TYPE AND DATES COVERED
Draft (22 JUL 2010 – 21 SEP 2011)

4. TITLE AND SUBTITLE
Environmental Change and Fragile States—Early Warning Needs, Opportunities, & Intervention

5. FUNDING NUMBERS
Contract: MANCON
Task: MAN0B
Subtask: MAN0B.07

6. AUTHOR(S)
Jeremey Alcorn
Jennifer Bitting
Kelli Canada
Keith Herrmann
Roger Lueken
John Ruffing
Kristie Siroonian

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Logistics Management Institute (LMI)
2000 Corporate Ridge
McLean, VA 22102-7805

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
Army Environmental Policy Institute
9301 Chapek Road, Bldg 1458 Fort Belvoir, VA 22060-5527 Technical Monitor: Steven Hearne

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

10 SUPPLEMENTARY NOTES
Cover Graphics: The report cover reflects a composite of images reflecting the diverse yet challenging environment of the African Savanna, a tropical grassland biome, and photos of US military engagement activities in the region. Photos are provided courtesy of US Africa Command, highlighting the Combined Joint Task Force-Horn of Africa (bottom left) during casualty scenario training for Rwanda Defense Force battalion medical officers, and the 402nd Civil Affairs Battalion (bottom right) befriending civilian high school students in Djibouti (Photo Credits: Staff Sgt. Katherine McDowell, USAF and Master Sgt. Dawn M. Price, USAF, respectively).

12a. DISTRIBUTION/AVAILABILITY STATEMENT
Unclassified/Unlimited Distribution.

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*
Weak and fragile states have emerged as one of the predominant threats to global security and stability. Early and accurate identification of fragile states can help structure more successful interventions, but environmental change has not received adequate consideration. Integrating environmental security mechanisms into existing early warning tools and/or engagement processes could help meet emerging Humanitarian Assistance and Disaster Relief, Stability, Security, Transition, and Reconstruction, and Military to Military engagement mission requirements at the strategic, operational, and tactical levels. This study identifies the relevant Army mission roles, needs, and existing early warning approaches/systems that could be leveraged to incorporate environmental security and, potentially, climate security factors. It identifies the current gaps/disconnects that represent barriers to the Army better utilizing geospatial capable, knowledge products that can meet internal mission needs and enhance “smart power” capabilities (defense, diplomacy, and development). The report presents detailed technical findings on the available data, integration, analysis approaches as well as the relevant USG capabilities and systems identified through the course of the study. It then proposes a full spectrum (conflict, instability, and fragility), conceptual framework that integrates sectors and natural resource as well as a functional analysis, early warning, and enablement architecture intended to operationalize this framework. It explores the need for capabilities to address the national security implications of climate change and discuss the framework’s extension to understand climate change impacts on natural resources in a manner relevant to US national security interests and military missions.

14. SUBJECT TERMS
Fragility; Natural Resources; Environmental Factors; Early Warning; Instability; Conflict;

15. NUMBER OF PAGES
212

1) PRICE CODE

2) SECURITY CLASSIFICATION OF REPORT	3) SECURITY CLASSIFICATION OF THIS PAGE	4) SECURITY CLASSIFICATION OF ABSTRACT	5) LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	None

NSN 7549-01-280-5500

Standard Form 298 Rev. 12/00
Prescribed by ANSI ST. 239-18
880922

THIS PAGE INTENTIONALLY LEFT BLANK

Preface

This report was prepared under contract for the Army Environmental Policy Institute (AEPI) by Logistics Management Institute (LMI). The views expressed do not necessarily reflect the official policy or position of the Department of the Army, Department of Defense, or the United States Government.

The mission of AEPI is to assist the Army Secretariat in developing forward-looking policies and strategies to address environmental issues that may have significant future impacts on the Army. In the execution of this mission, AEPI is further tasked with identifying and assessing the potential impacts on the Army of emerging environmental issues and trends.

This report discusses the efforts conducted under MANCON Contract, LMI Task Number MAN0B, Subtask Number MAN0B.07, “Environmental Factors and Fragility.” The purpose of the Subtask is to study existing fragility-related challenges and opportunities to integrate natural resource considerations into existing conflict, instability and fragility early warning tools. AEPI tasked LMI to identify new integrative mechanisms and capabilities that help meet humanitarian assistance disaster recovery (HADR); stability, security, transition, and reconstruction (SSTR); and military-to-military (mil-to-mil) engagement mission needs. AEPI requested the study because emerging demands for US “smart power,” NSPD-44, and DoDI 3000.5 drivers require better means to integrate natural resource and environmental factors into the Army’s strategic instability-fragility analyses and operational engagement opportunity assessments. Furthermore, the 2010 Quadrennial Defense Review Report (QDR), 2010 National Security Strategy (NSS), and 2011 National Military Strategy (NMS) also demand that the Army and Department of Defense (DoD) be better equipped to engage in interagency collaboration that supports proactive, integrated “whole-of-government” and state fragility management strategies.

The project’s goal is to provide AEPI and the Assistant Secretary of the Army for Installations, Energy and Environment with awareness of relevant military missions and roles, a common conceptual language, and an overview of existing conflict-instability-fragility early warning approaches and systems that could be leveraged to incorporate natural resource, environmental, and, potentially, climate security factors. We also identify barriers to the Army’s further use of geospatial-capable knowledge products, which once overcome, will enable the Army to better meet its mission needs and enhance the smart power capabilities—diplomacy, development, and defense (3Ds)—essential in accomplishing national security missions in an increasingly complex future security environment. We offer recommendations for a framework and architecture that supports the Army, DoD, and US government strategic early warning and operational planning needs, particularly in light of emerging mission-relevant environmental and climate shock threat multipliers.

Please direct comments pertaining to this paper to:
Director, Army Environmental Policy Institute
9301 Chapek Road, Bldg 1458
Fort Belvoir, VA 22060-5527

Acknowledgments

The AEPI Project Manager and Technical Monitor on this task was Mr. Steven Hearne. The LMI Project Leader for this subtask was Mr. Jeremey Alcorn.

This report would not have been possible without the contributions of the following individuals:

LTC Paul Schimpf, Office of the Secretary Defense (Policy)
Ms. Esther McClure, Office of the Secretary Defense (Policy)
Mr. Sam Binkley, Office of the Secretary Defense (Policy)
Mr. Steven Ayers, Global Warning Enterprise, J-2, Joint Staff
Mr. Deane Swickard, US Africa Command (USAFRICOM)
Mr. Artur Kolodziejski, USAFRICOM
Ms. Myrna Lopez, US Southern Command (USSOUTHCOM)
Dr. Sean O'Brian, Defense Advanced Research Projects Agency (DARPA)
LTC Shannon Beebe, Formerly of the Defense Security Cooperation Agency (DSCA)
Mr. James Pugel, Defense Intelligence Agency (DIA)
Mr. Dana Dillon, G-2, HQDA, US Army
Ms. Renee Carlucci, Center for Army Analysis (CAA)
Mr. Bill Goran, US Army Corps of Engineers (USACE)
Dr. Cynthia Irmer, US Department of State
Dr. S. Tjip Walker, US Agency for International Development (USAID)
Ms. Cynthia Brady, USAID
Mr. Kirby Reiling, USAID
Dr. Geoffery Dabelko, Environmental Change and Security Program (ECSP), Woodrow Wilson Center for Scholars
Dr. J. Joseph Hewitt, Center for International Development and Conflict Management (CIDCM), University of Maryland
Dr. Jennifer Hazen, University of Texas at Austin
Dr. Josh Busby, University of Texas at Austin
Dr. Cullen Hendrix, University of North Texas
Dr. Idean Salehyan, University of North Texas
Dr. Clionadh Raleigh, Trinity College
Mr. Peter Nardulli Cline Center for Democracy, University of Illinois
Mr. Kalev Leetaru, University of Illinois at Urbana-Champaign
Mr. Aaron Frank, George Mason University (GMU)
Mr. Mohammad Mussavi Rizi Seyed, GMU
Mr. Maciek Latek, GMU
Dr. Armando Geller, Group W
Dr. Christine Youngblut, Institute for Defense Analyses (IDA)
Ms. Christine Parthemore, Center for New American Security (CNAS)
Mr. Thomas M. Parris, iSciences, LLC.

Executive Summary

Weak states and fragile regions are emerging as one of the predominant threats to global security and stability. Early identification of this fragility and accurate understanding of the underlying security, governance, economic, and social dynamics can help structure more informed, efficient, and effective responses. Natural resources and the environment play critical roles in human and societal welfare, particularly with the economies of many fragile states heavily dependent on agriculture and natural resource services. The United Nations Environmental Programme has asserted that "at least forty percent of all intrastate conflicts [since 1950] have a link to natural resources" and that "at least eighteen violent conflicts have been fuelled" by natural resource issues since 1990.[1] Given this and the demands of US "smart power,"[2] National Security Presidential Directive 44, and Department of Defense Instruction 3000.5, the US Army and Department of Defense (DoD) increasingly require means to integrate natural resource and environmental change when analyzing and monitoring conflict-instability-fragility at the strategic level as well as to inform engagement opportunities of regional combatant commands (COCOMs).

As a predominantly land-based force, the Army is often assigned a primary "boots on the ground" role to support fragile states and protect US interests that are at imminent risk during periods of increased instability or emergent conflict. Because responding to these types of situations places a significant burden on already stressed personnel, equipment, and supporting infrastructure, the Army must improve its organic capability to predict when and where these situations are likely to occur and understand how to effectively support proactive US efforts to mitigate beforehand. The ability to do so will help the Army to provide appropriate, measured responses and contribute to proactive engagements that fully considers current and future mission requirements and available resources.

[1] UNEP, From Conflict to Peacebuilding: The Role of Natural Resources and the Environment, 2009, p. 5, www.unep.org/pdf/pcdmb_policy_01.pdf

[2] As defined by Richard L. Armitage and Joseph S. Nye, Jr., "Smart power means developing an integrated strategy, resource base, and tool kit to achieve American objectives, drawing on both hard and soft power."

Various analytical frameworks provide conflict, instability, and fragility early warning, but natural resources and environmental change have generally not been incorporated. The Army is keenly aware of how natural resources and other environmental factors can and do impact its own operational readiness and training capabilities. Integrating them into existing early warning tools and regional engagement planning should enable the Army to more proactively support humanitarian assistance and disaster relief (HADR); stability, security, transition, and reconstruction (SSTR); and military-to-military (mil-to-mil) engagement mission planning, execution, effectiveness, and efficiency. Likewise, by leveraging an open-architecture approach, such as the Interagency Conflict Assessment Framework, the Army and DoD could better enable interagency efforts that pool resources and support proactive "whole-of-government" strategies for minimizing state fragility, as required by the 2010 *Quadrennial Defense Review*, 2010 *National Security Strategy*, and 2011 *National Military Strategy*.

Building on key findings from the 2010 Army Environmental Policy Institute (AEPI) report on environmental factors in forecasting fragility, this study identifies the relevant Army mission roles (including HADR, mil-to-mil engagement, and initial public service provisioning in SSTR situations), needs, and existing analysis approaches and early warning capabilities that could incorporate natural resource, environmental, and possibly climate security factors. As US military missions grow in complexity, so does the need for conflict-instability-fragility analysis, early warning, and prediction to provide Army personnel situational awareness across human activity sectors and natural resources. To this end, we identify several relevant, existing approaches—including the Army Forecast and Analysis of Complex Threats III, Defense Advanced Research Projects Agency Integrated Crisis Early Warning System, and US Agency for International Development Fragility Alert Lists—to explore existing capabilities and gaps.

Our overview of capabilities presents a broad spectrum of open-source quantitative data sources, statistical and geospatial analysis options as well as qualitative, expert- or social network-based, ground-truthing architectures. These existing capabilities were found to leverage approaches and methods supportive of US foreign policy objectives across the full spectrum of conflict (from strong peace to failed states). This report also identifies challenges for the use of geospatial products. Most of the approaches, models, tools, and systems assessed do not provide situational awareness of human activity sector (agriculture, energy, water, etc.) performance below the national level or link these dynamics to relevant Army or DoD mission roles. They largely do not include natural resource or environmental factors or consider the conceptual contexts (resilience, vulnerability, or adaptation) needed to begin addressing climate change challenges.

The fragility approach can play an important role as a bridging concept between the mission relevance of conflict and instability and more functional human activity sectors, natural resources, and climate change factors. AEPI's engagement efforts with Army, DoD, and other agencies mission and analysis communities identified relevant programs, offices, and functionalities that could benefit from more integrated conflict, instability, and fragility analysis as well as early warning, predictive, and exploratory capabilities. In this context, we present findings on the available data, integration, and analysis approaches as well as the relevant government capabilities.

This report introduces a conflict, instability, and fragility conceptual framework that integrates human activity sectors and natural resources. We propose a functional analysis, early warning, and enablement architecture to operationalize this framework. We also explore the need for capabilities to address the national security implications of climate change and discuss the framework's extension to climate impacts on natural resources in a manner relevant to US national interests.

We recommend the following:

- Develop and socialize the fragility early warning and environmental change concept to support Army contingency planning, situational awareness, and regional security engagement roles, including the related policy implications.
- Devote government efforts to conceptualizing a modular fragility early warning system that integrates natural resource factors and all source data.
- Explore a regional COCOM pilot utilizing geospatial and social science approaches to better understand fragility and natural resources dynamics.
- Study relevant instances of Army, DoD, and interagency decision making and how access to data, analysis, and early warning produced better and less costly proactive decisions.
- Establish a government technical community of practice to adapt existing capabilities that address sector, natural resource, and climate factors.

Our efforts, findings, and recommendations support a growing dialog on the Army and DoD use of fragility in a broader context than SSTR. They also point to the demonstration of fragility-based analysis, early warning, and enablement systems. Such systems could better support DoD, regional COCOM, and Army command missions in a complex future security environment.

Contents

Chapter 1 Introduction..1-1
RELEVANCE 1-2
US POLICY DRIVERS 1-3
CONCEPTUAL LEXICONS 1-6
KEY CONCEPTS.. 1-7
Conflict 1-8
Instability 1-9
Fragility... 1-10
Vulnerability.. 1-12
Resilience.. 1-13
Adaptation 1-15
REPORT OVERVIEW... 1-15
Chapter 2 Study Approach...2-1
STAKEHOLDER AND RESOURCE OUTREACH.................................. 2-1
Identification 2-2
Engagement 2-2
EARLY WARNING CAPABILITIES REVIEW 2-5
Data Search and Selection.. 2-6
Analyses Modes 2-6
Tools, Systems, and Output Products 2-7
Chapter 3 Mission and Fragility, Capabilities, and Gaps 3-1
MISSION AND FRAGILITY... 3-1
NEEDED CAPABILITIES 3-3
PREVIOUSLY IDENTIFIED TECHNICAL GAPS 3-5
Geospatially Explicit Data and Analysis.. 3-5
Temporally Explicit Data and Analysis.. 3-6
Data Accessibility, Usability, and Utility 3-7
Integrated and Triangulated Fragility Approaches 3-8

Chapter 4 Resources and Capabilities 4-1
DATA 4-2
Data Aspects 4-2
Data Types 4-5
Data Providers 4-10
CLASSIFICATION, INTEGRATION, AND MONITORING 4-13
Processing and Classification 4-13
Data Integration 4-15
Data Monitoring 4-16
ANALYSIS APPROACHES AND MODELS 4-16
Statistical Analysis and Modeling 4-17
Qualitative Analysis and Fusion 4-18
Agent-Based Models 4-19
Bayesian Analysis 4-20
MODELS AND TOOLS 4-20
Predictive Models and Tools 4-21
Exploratory and Situational Awareness Tools 4-22
Scenario Planning Approaches and Tools 4-23
EARLY WARNING SYSTEMS AND DECISION MAKING 4-25
RESOURCE SUMMARY 4-26
Chapter 5 Proposed Framework and Architecture 5-1
PROPOSED FRAGILITY FRAMEWORK 5-1
FUNCTIONAL ARCHITECTURE 5-3
Proposed Architecture Components 5-3
Component A: Define Approach and Select Data (Knowledge Center) 5-4
Component B: Assimilate and Integrate 5-6
Component C: Analyze and Synthesize 5-12
Component D: Inform and Collaborate 5-15
Chapter 6 Climate and Security Nexus 6-1
CLIMATE CHANGE AND NATIONAL SECURITY 6-1
CLIMATE SECURITY CHALLENGES 6-3
Border and EEZ Disputes 6-4

Water Stress 6-5
Food Production Decline 6-5
Climate-Augmented Disruptions and Disasters 6-6
International Mass Migration 6-6
Fragility, Instability, and Failed States 6-7
OPPORTUNITIES 6-7
PROPOSED ARCHITECTURE'S UTILITY 6-9
Chapter 7 Conclusions and Recommendations 7-1

Appendix A Points of Contact and Potential Resources
Appendix B List of Outreach Meetings
Appendix C Intra-Army Working Group Draft Charter
Appendix D Inter-Agency Forum on State Instability and Fragility Approaches and Natural Resource
Appendix E Data Matrix
Appendix F Remote Sensing
Appendix G Analysis Aids, Models, Tools, and Systems
Appendix H References
Appendix I Glossary
Appendix J Abbreviations

Figures

Figure 1-1. Failed State SSTR Intervention 1-6
Figure 1-2. AEPI 2010 Report Thought Map (Generated by Wordle.net) 1-7
Figure 3-1. Stability Mission Requirements 3-2
Figure 4-1. Study Data to Decision Support Category Approach 4-1
Figure 4-2. Levels of Geospatial Scale 4-3
Figure 4-3. Analysis Domains 4-4
Figure 4-4. Vector and Raster Formats 4-6
Figure 4-5. Electromagnetic Spectrum 4-8

Figure 4-6. Remote Sensing Technologies 4-9
Figure 5-1. Proposed Conflict, Instability, Fragility, Sector, and Natural Resource Framework 5-2
Figure 5-2. Proposed Functional Architecture Components 5-4
Figure 5-3. Potential Concept Relationship Mapping Inquiry 5-5
Figure 5-4. Knowledge Center Data Quality and Resource Availability Summary 5-6
Figure 5-5. Example of Architecture Analysis Approach 5-12
Figure 5-6. Example of Interactive Dashboard in DARPA ICEWS 5-17
Figure 6-1. Integrated Assessment Framework of Climate-Society Interaction 6-8
Figure 6-2. Proposed Architecture's Extension for Climate Impact Analysis 6-10
Figure 6-3. Example of Proposed Architecture's Use for Climate Analysis 6-10
Figure 6-4. Example of Climate Vulnerability in North Africa 6-11

Tables

Table 2-1. Stakeholder Organizations and Status 2-3
Table 3-1. Needs for Capabilities 3-4
Table 4-1. Levels of Processing for Remote Sensing Data 4-14
Table 4-2. Identified Approaches, Models, Tools, and Systems for Analyzing, Monitoring, and Predicting Aspects of Conflict, Instability, or Fragility 4-29

Chapter 1
Introduction

The Army Environmental Policy Institute (AEPI) tasked LMI to study the conceptualization and integration of natural resource, environmental factor, and climate change into existing analysis and early warning tools of state fragility as well as to identify ways to help better meet humanitarian assistance disaster recovery (HADR); stability, security, transition, and reconstruction (SSTR); and military-to-military (mil-to-mil) engagement mission needs.[1] With "at least eighteen violent conflicts [being] fuelled" by natural resource issues since 1990,[2] AEPI requested this study to better understand the available and emerging means to integrate natural resource and environmental factors into the Army's strategic conflict-instability-fragility analyses and operational engagement opportunity assessments. The 2010 *Quadrennial Defense Review Report* (QDR), 2010 *National Security Strategy* (NSS), and 2011 *National Military Strategy* (NMS) also demand that the Army and Department of Defense (DoD) be better equipped to engage in interagency collaboration that supports "smart power"[3] "whole-of-government" state fragility management strategies, and better understand nontraditional threat multipliers, such as climate change.

This study provides AEPI and the Assistant Secretary of the Army for Installations, Energy and Environment, ASA(IE&E), an overview of relevant military missions and roles, a common conceptual framework, and an awareness of existing conflict-instability-fragility analysis approaches, early warning systems capable of incorporating environmental security and, potentially, climate security factors. We also identify barriers to Army use of relevant geospatial-capable knowledge products, which when overcome, will enable the Army to better meet its mission needs and enhance the smart power capabilities—diplomacy, development, and defense (3Ds)—that are essential in protecting national security interests in an increasingly complex future security environment. We propose a fragility-based framework and functional architecture that helps address Army strategic early warning and operational planning needs, particularly in light of

---

[1] Commonly referred to as mil-to-mil engagement, Joint Publication (JP) 1-02 defines "military engagement" as "[r]outine contact and interaction between individuals or elements of the Armed Forces of the United States and those of another nation's armed forces, or foreign and domestic civilian authorities or agencies to build trust and confidence, share information, coordinate mutual activities, and maintain influence." More background can be found in JP 3-0.

[2] UNEP, From Conflict to Peacebuilding: The Role of Natural Resources and the Environment, 2009, p. 5, www.unep.org/pdf/pcdmb_policy_01.pdf.

[3] The term "smart power" was defined by Richard Armitage and Joseph Nye, Jr. as "developing an integrated strategy, resource base, and tool kit to achieve American objectives, drawing on both hard and soft power" in Cohen, C., Nye, J.S. and Armitage, R., Center for Strategic and International Studies, Commission on Smart Power: A smarter, more secure America, November 6, 2007, csis.org/files/media/csis/pubs/071106_csissmartpowerreport.pdf.

emerging mission-relevant natural resource, environmental change, and climate shock threat multipliers.

In the remainder of this chapter, we summarize the military relevance of conflict, instability, and fragility to natural resources, environmental factors, and climate change. We also introduce the challenges of a diverse interagency, conceptual lexicon, explore key concepts (conflict, instability, fragility, vulnerability, resiliency, and adaptation), and propose working definitions for this report. We conclude with an overview of the remainder of the report.

RELEVANCE

The US military recognizes the negative effects of conflict, instability, and fragility on US national security interests and has acknowledged the natural resource link to these conditions. Secretary of Defense Robert Gates stated, "We also know that over the next 20 years and more, certain pressures—population, resource, energy, climate, economic, and environmental—could combine with rapid cultural, social, and technological change to produce new sources of deprivation, rage, and instability." He also commented, "But, overall, looking ahead, I believe the most persistent and potentially dangerous threats will come less from ambitious states, than failing ones that cannot meet the basic needs—much less the aspirations—of their people."[4] This suggests that we should identify, understand, and proactively diffuse conditions that give rise to the persistent threats posed by fragile and vulnerable societies in the middle tier between developed and failing.

The *2011 Army Posture Statement* notes, "The demand for resources such as water, energy, and food will increase competition and the propensity for conflict. Even as countries develop more efficient uses of natural resources, some countries, particularly those with burgeoning middle classes, will exacerbate demands on already scarce resources." It also identifies failing states, along with proliferation of weapons of mass destruction, as one of the trends of greatest concern.[5] Climate change could increase the complexity and severity of natural resource constraints and their effects on stability. "Climate change acts as a threat multiplier for instability in some of the most volatile regions of the world."[6]

Beyond simply reacting to conflict, the US military desires to take a more proactive role in understanding and influencing factors affecting fragility and instability. Although the armed forces' primary mission is to prepare to defeat adversaries and prevail in a fight, DoD thinking is expanding from a focus on kinetic capabilities toward augmented or new mission roles, such as SSTR, as evidenced by the 2005 release of DoD Directive (DoDD) 3000.5. Other military thought leaders, such Retired General Anthony Zinni and the late Lieutenant Colonel Shannon

[4] Robert M. Gates, Remarks at US Global Leadership Campaign Tribute Dinner, Washington, DC, July 15, 2008.

[5] Department of the Army, *2011 Army Posture Statement*, March 2011.

[6] CNA Corporation, *National Security and the Threat of Climate Change*, 2007.

Beebe, have gone further, suggesting that regional combatant command (COCOM) engagement and proactive, interagency human security missions can help shape the future security environment, particularly in ways that limit or obviate the need for military intervention into the future.[7,8] In the early phases of any conflict, in contingency operations, or even in some natural disasters in complex environments, the military can become responsible for security, reconstruction, and providing basic sustenance and public services. In recent years, the lines separating war, peace, diplomacy, and development have blurred, no longer fitting the traditional, stovepiped organizational charts remaining from 20th century doctrine. The elements and stakeholders working in the international arena—military and civilian, government and private—are increasingly learning to cross normal boundaries to better work together to achieve results.[9]

As the role of the US military evolves, instability, fragility, and vulnerability are becoming increasingly important. Likewise, a better understanding of the underlying dynamics that accelerate instability or sustain conflicts, such as natural resources, becomes more critical to mission success. For instance, the United Nations Environment Programme (UNEP) has asserted that "at least forty-percent of all intra-state conflicts [since 1950] have a link to natural resources" and that "at least eighteen violent conflicts have been fuelled" by natural resource issues since 1990.[10] As the significance and relationship of natural resources and environmental factors with fragility and conflict becomes more evident,[11] the military will have a greater need for effective approaches to analyzing, planning for, and responding to these dynamic conditions.

US Policy Drivers

The need to understand conflict, instability, fragility, and the relevance of natural resource and environmental factors is driven by the military's evolving role in diplomacy and development as well as the corresponding expansion of US government, DoD, and Army policies. Also, the changing national security environment and operational needs during peacekeeping and irregular or full-scale conflict necessitate a broader perspective on the variables that influence mission strategies and execution. As stability operations are a key responsibility of the Army and the US military overall, and as environment and natural resources become increasingly relevant to both warfighting and diplomacy, understanding

[7] Butts, K, Water & Health: Security and Stability Partnerships, Center for Strategic Leadership, health.usf.edu/publichealth/pdf/Kent%20Butts%20Water%20&%20Health.pdf.

[8] Beebe, S. and Kaldor, M. 2010. The Ultimate Weapon is No Weapon. Public Affairs. New York.

[9] See Note 4, this chapter.

[10] See Note 2, this chapter.

[11] Both Burke et al. 2009 and Hsiag et al. 2011 provided fresh analysis and peer reviewed evidence to this assertion in their articles in the Proceedings of the National Academy of Sciences and prestigious journal *Nature*, respectively. They also extend the study of conflict and natural resource to past, present, and future climatic conditions and changes.

the myriad relationships between fragility and social, economic, political, and environmental factors becomes a mission enabler because it not only provides situational awareness for decisions but also targeted areas to act upon.

US policy has evolved to keep pace with the global security environment and provide direction to the military as its role changes. These policy and guidance documents compel action and drive the need for better information and analysis:

- National Security Presidential Directive (NSPD)-44
- Presidential Policy Directive on Global Development
- 2010 NSS
- 2011 NMS
- 2010 QDR
- *Leading Through Civilian Power: The First Quadrennial Diplomacy and Development Review 2010 (*QDDR*)*
- DoDI 3000.5
- *2010 Joint Operating Environment* (JOE)
- Army Field Manuals (FMs): FM 3-0, *Operations*, including Change 1, and FM 3-07, *Stability Operations*.

US national security policy increasingly emphasizes the need for better coordinated planning, programming, and use of government hard and soft power, or smart power, and strongly advocates its role in full-spectrum operations. The NMS emphasizes this new imperative, its necessity for ensuring stability, and key objectives to "strengthen international and regional security" and "counter violent extremism," which squarely point to the increased relevance of and operational need to reduce fragility.[12]

This smart power emphasis and strategic framework suggest that the Army's doctrinal inclusion of fragility for SSTR purposes was timely and appropriate but may still be too limited in its current definitional scope. Given these evolving mission needs, a broader aperture or conception of the fragility concept can facilitate understanding of its relevance and generate greater "unity of effort" for the full spectrum of operations in future military missions and US government actions.

In 2005, DoD Directive (DoDD) 3000.5 signaled a change in the US military paradigm and policy in making SSTR missions equal in importance to combat

[12] Chairman, Joint Chiefs of Staff, *2011 National Military Strategy*, www.jcs.mil/content/files/2011-02/020811084800_2011_NMS_-_08_FEB_2011.pdf.

operations. DoD policy guidance required a greater capacity to effectively support US government missions across the spectrum of conflict, support civilian security, provide services, restore infrastructure, and provide humanitarian relief.[13] US policymakers and thought leaders seem to be increasingly shifting from a "traditional" national security framework to a "human security" approach, which includes energy, natural resource, and environmental components.[14,15] In short, policy and doctrine are slowly starting to catch up with the realities regional COCOM and in-theater personnel face daily.

Operationalizing the fragility concept requires and complements Army transition from SSTR operations to an expansion of its commands' support for HADR and mil-to-mil engagement missions, particularly for regional COCOMs. In doing so, the Army mission relevance becomes more evident as fragility monitoring and early warning approaches proactively support commands' situational awareness and the visibility of non-traditional threats prior to the emergence of instability or conflict. Through rapid and informed interagency response strategies, the military and its US government partners can act to avoid delayed responses, which often limit the available options, demand more resources, and entail greater risk to both the warfighter and mission. For example, awareness of countries with increasing fragility could inform the development of theater security cooperation plans and prioritization of engagement activities. Fragility analysis and exploratory approaches that include natural resources could also generate inputs for use in scenario and military contingency planning, assessing capabilities and gaps, and programming for or partnering with other government agencies.

The Army and US Agency for International Development (USAID) have both sought to identify fragility and environmental factor analytical approaches, monitoring mechanisms, and early warning systems as well as explore their compatibility with environmental change and climate vulnerability assessment approaches. In particular, they have examined how fragility could be used as an integrative concept to address natural resource and environmental threat multipliers.

Beyond any predictive insights that may be gained through a better understanding of fragility and other environmental factors, such as climate change, increased understanding of underlying dynamics, relationships, and causes may substantially benefit Army training exercises and operations. In executing their respective missions, Army elements—ranging from headquarters operations to troops in the field—require timely access to information for operational plans and decision making, particularly that concerning the allocation of resources and increases in

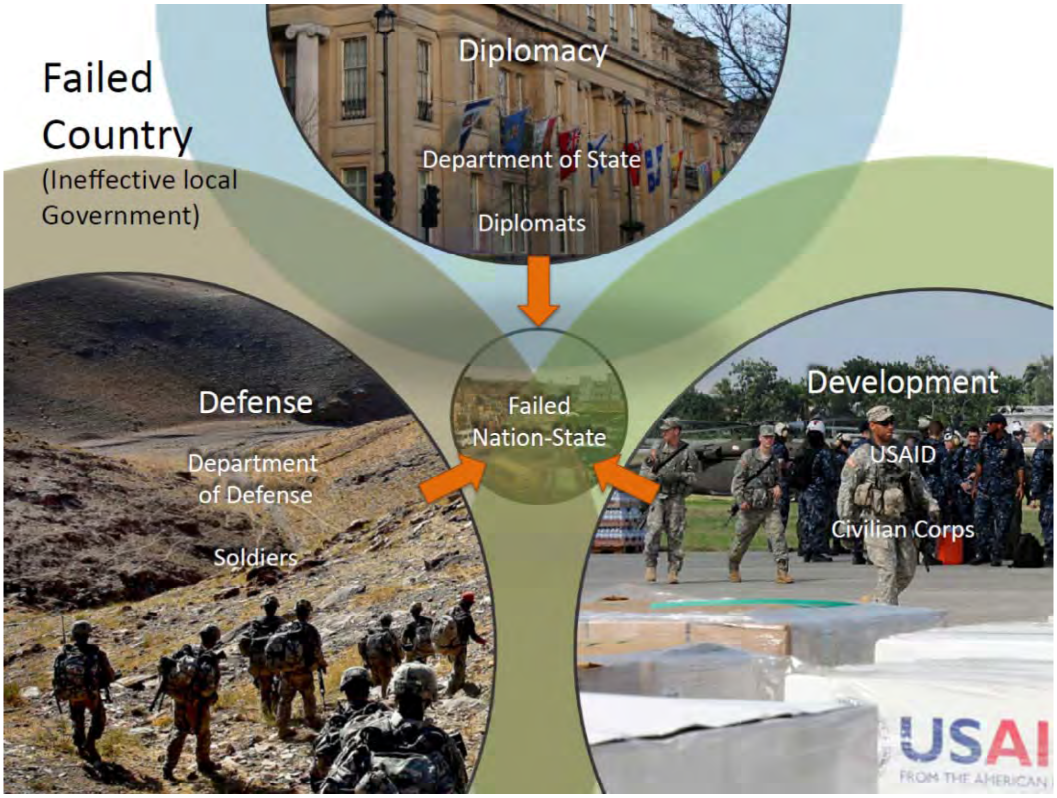
[13] DoDI 3000.5, Stability Operations, September 16, 2009, www.dtic.mil/whs/directives/corres/pdf/300005p.pdf.

[14] Carolyn Pumphrey, ed., *Global Climate Change National Security Implications* (Carlisle Barracks, PA: United States Army War College, Strategic Studies Institute, 2008), www.strategicstudiesinstitute.army.mil/pubs/display.cfm?pubID=862.

[15] DoD, *2008 United States National Defense Strategy*, 2008, www.defenselink.mil/news/2008%20National%20Defense%20Strategy.pdf.

readiness. Broadening government collaboration and international partnering could result in further efficiencies when a whole-of-government approach is necessary for mission success, such as in SSTR operations[16] (Figure 1-1).

Figure 1-1. Failed State SSTR Intervention



CONCEPTUAL LEXICONS

Terms for Aligning National Power	
3Ds	Diplomacy, development, and defense
DIME	Diplomatic, information, military, and economic
Smart Power	Hard power, soft power, and interagency
Unity of Effort	DoD joint doctrine

The US Government is trying to align its policy efforts to more effectively use all the instruments of power at its disposal. However, this whole-of-government/interagency approach is often challenged by the lack of common conceptual lexicons. The differences in terminology, language, and approach can hamper government understanding of the problems and unity of effort in addressing non-traditional national security threats and challenges. Although higher-level policy documents share and shape

[16] This direction aligns with the Government Accountability Office's assessment of challenges, needs, and recommendations as elaborated in report GAO-07-549, titled "Military Operations: Actions Needed to Improve DoD's Stability Operations Approach and Enhance Interagency Planning," www.gao.gov/new.items/d07549.pdf.

concepts, DoD, Department of State, and USAID strategic and operational lexicons are sometimes inconsistent, particularly in real world use.

Over the last two decades, the US national security paradigm and interests have evolved, giving rise to new concepts to help frame the non-traditional challenges faced in the 21st century. During the course of the 2010 AEPI study, it became clear that the evolving integrative concepts, such as fragility, were gaining traction within the US national security community,[17] and the report highlighted numerous terms for key integrative concepts relevant to US Army missions. Figure 1-2 illustrates this conceptual lexicon diversity.

Figure 1-2. AEPI 2010 Report Thought Map (Generated by Wordle.net)

In short, national security (particularly the 3Ds), natural resource/environmental, and climate communities of practice are increasingly faced with the necessity of jointly addressing the complexities and interdependencies of modern non-traditional threats. However, these communities have conceptual and lexicon divergences or mismatches that can result in lack of understanding and poorer unity of effort. Clearly, a concerted dialog is needed to socialize and map the concepts of conflict, instability, fragility, vulnerability, resiliency, and adaptation to make progress on these core issues and new challenges, such as climate change. In the following section, we explore various understandings of these concepts and offer working definitions for the purposes of this report.

KEY CONCEPTS

As discussed, the differing terminology of various agencies and disciplines makes collaboration more challenging. Organizations working in the realm of conflict,

[17] AEPI, *Environmental Factors in Forecasting State Fragility*, June 30, 2010, www.aepi.army.mil/.

instability, and fragility range from academia to US government agencies to international nonprofit organizations. The disciplines of those working in these organizations range from military strategists to international disaster aid workers to re-research anthropologists. Each organization and discipline has a unique culture, perspective, purpose, and language, but much can be gained from their cooperation. To successfully collaborate, organizations must effectively communicate, which is more likely when using a common, or at least more aligned, lexicon. The following subsections explore concepts and definitions for

- conflict,
- instability,
- fragility,
- vulnerability,
- resiliency, and
- adaptation.

In discussing each concept, we propose working definitions for the purposes of and use within this report.

Conflict

U.S. Army Staff Sgt. Clint Koerperich, left, patrols with Afghan soldiers to investigate possible insurgent cache locations in the Zormat district of Afghanistan. The soldiers acted on a tip provided by the Guardians of Peace program. (US Army photo by Sgt. 1st Class Matthew Smith, February 5, 2011.)

Although the concept of conflict seems simple, variations in its definition can narrow or broaden its meaning and application, particularly in the context of international relations, human security, and natural resources. Indeed, the growing body of conflict literature emphasizes the necessity to properly frame and define what is considered a conflict.[18] In studying the connections between natural resources and violent conflict, the differing definitions of civil wars, armed conflict, and battle death thresholds (in addition to scale, temporal, and missing data challenges) contribute to the divergence in findings.[19] Is the conflict in question an interstate war, civil war, insurgency, or social tension resulting in violence and protests? A recent UNEP

[18] Ross, Michael, What Do We Know about Natural Resources and Civil War?, *Journal of Peace Research*, 41(3), 337-356, 2004, http://jpr.sagepub.com/content/41/3/337.full.pdf+html.

[19] Ibid.

report, *From Conflict to Peacebuilding: The Role of Natural Resources and the Environment*, offers a broader definition:

> Conflict is a dispute or incompatibility caused by the actual or perceived opposition of needs, values and interests. In political terms, conflict refers to wars or other struggles that involve the use of force…the term 'conflict' is understood to mean violent conflict.[20]

Likewise, aligning with this conception presented in the 2010 NSS, Joint Publication (JP) 1-02, DoD's *Dictionary of Military and Associated Terms*, defines the US military's specific understanding of conflict as follows:

> An armed struggle or clash between organized groups within a nation or between nations in order to achieve limited political or military objectives. Although regular forces are often involved, irregular forces frequently predominate. Conflict often is protracted, confined to a restricted geographic area, and constrained in weaponry and level of violence. Within this state, *military power* in response to threats *may be exercised in an indirect manner while supportive of other instruments of national power* [emphasis added].[21]

For this report, we consider conflict to include armed struggle between nations or within a nation as well as nonviolent social tension between internal groups.

Instability

As originally defined by the Political Instability Task Force, formed to investigate "severe political conflicts and regime crises,"[22] instability is the occurrence of events such as revolutionary wars, ethnic wars, adverse regime changes, genocides, and politicides.[23]

According to USAID personnel, the Agency's Alert Lists Report adopts a definition of instability that refers to the future likelihood that a country will experience a coup d'etat, a civil war, a government collapse, or some other destabilizing event that will hamper or entirely disrupt the government's ability to function. A range of factors relating to attributes of the state in the economic, political, social, and security domains drives the risk for future instability.

---

[20] UNEP, From Conflict to Peacebuilding: The Role of Natural Resources and the Environment, 2009, p. 7, www.unep.org/pdf/pcdmb_policy_01.pdf.

[21] DoD, *Dictionary of Military and Associated Terms*, Joint Publication 1-02, November 8, 2010 (as amended through May 15, 2011), www.dtic.mil/doctrine/new_pubs/jp1_02.pdf.

[22] Monty G. Marshall, *Political Instability Task Force Fact Sheet* (Arlington, VA: George Mason University, School of Public Policy, Center for Global Policy, 2009), globalpolicy.gmu.edu/pitf/.

[23] Robert H. Bates, et al., Political Instability Task Force Report: Phase IV Findings (McLean, VA: Science Applications International Corporation, 2003), globalpolicy.gmu.edu/pitf/.

USAID assesses a nation state's risk of instability using factors such as neighborhood conflict, militarization, infant mortality, economic openness, partial democracy, and regime consistency.

DoDI 3000.5 focuses on state instability, but JP 1-02 does not define the term. DoD's current terminology does not focus as much on the hazard (instability) as on the operations and desired condition (stability). Thus, JP 1-02 provides insight into the military's conception of what instability is not, through its definition of stability operations, which include

> various military missions, tasks, and activities conducted outside the United States in coordination with other instruments of national power *to maintain or reestablish a safe and secure environment, provide essential governmental services, emergency infrastructure reconstruction, and humanitarian relief*.

For this report, we define instability as the risk of a destabilizing event or condition that hampers or disrupts a government's capacity to maintain a secure environment, sustain critical infrastructure, and provide essential government political, economic, and social services. Lack of internal provisioning and options for the nonviolent redress of grievances (governance failure) may warrant increased attention and monitoring, particularly given the resultant examples of instability, ranging from civil wars to protest movements, manifested during the 2011 "Arab Spring."

Fragility

Fragility is a known precursor to state instability, conflict, and collapse.[24] The German Development Institute's (DIE's) and United Nations Development Programme's (UNDP's) *User's Guide on Measuring Fragility* differentiates between a "fragile state" and a "fragile social situation":

> When fragility refers to the state, fragility is in fact a property of the political system. A 'fragile state' is incapable of fulfilling its responsibility as a provider of basic services and public goods, which in turn undermines its legitimacy.
>
> When fragility refers to society as a whole, violent conflict and other human-made crises constitute fragility itself. In this sense, fragility is a property of society and thus, being defined much more broadly, includes any kind of political, social or economic instability. This understanding of fragility is termed a 'fragile social situation.[25]

[24] See Note 17, this chapter.

[25] Javier Fabra Mata (DIE) and Sebastian Ziaja (UNDP), Users' Guide on Measuring Fragility, www.carleton.ca/cifp/app/serve.php/1245.pdf.

In addition, the Brookings Institution, creators of the *Index of State Weakness in the Developing World*'s index, used the term state "weakness" as an analog to state fragility. They define weak states as

> countries lacking the capacity and/or will to foster an environment conducive to sustainable and equitable economic growth; to establish and maintain legitimate, transparent, and accountable political institutions; to secure their populations from violent conflict and to control their territory; and to meet the basic human needs of their population.[26]

USAID's *Conflict, Fragility, and the Environment* describes its current concept of fragility as a

> characteristic of the relationship between the state and society, especially the extent to which the engagement between the state and society produces outcomes that are considered *effective* and *legitimate*…exist[ing] when the relationship between state and society is strained, if not contentious, producing results that are deemed by members of that society to be ineffective, illegitimate, or both.

Army FM 3-07, *Stability Operations*, defines a fragile state on the basis of the "Fragile States Framework" definition:

> Country that suffers from institutional weaknesses serious enough to threaten the stability of the central government … aris[ing] from several root causes, including ineffective governance, criminalization of the state, economic failure, external aggression, and internal strife due to disenfranchisement of large sections of the population. Fragile states frequently fail to achieve any momentum toward development [and can] generate tremendous human suffering, create regional security challenges, and collapse into wide, ungoverned areas that can become safe havens for terrorists and criminal organizations.

This broader context of social fragility is increasing the focus on the implications of environmental factors and natural resource sectors' relationship to fragility. Defense and development leaders are increasingly concerned about the implications of natural resource abundance or degradation on fragility, particularly its social and economic components, which can lead to future declines in political and security conditions. Given climate change's potential implications for the water, food, and energy sectors, a significant concern is that countries with limited resilience and adaptive capacity could become even more fragile.[27] Increased fragility directly translates into reduced government effectiveness, which, when coupled with a lack of legitimacy, carries serious national security implications in terms of weak and failed states.

[26] Susan Rice and Stewart Patrick, *Index of State Weakness in the Developing World* (Washington, DC: The Brookings Institution, 2008), www.brookings.edu/reports/2008/02_weak_states_index.aspx.

[27] Dennis C. Blair, *Annual Threat Assessment of the US Intelligence Community for the Senate Select Committee on Intelligence*, February 2, 2010, intelligence.senate.gov/090212/blair.pdf.

For this report, FM 3-07's functional definition of fragility applies with the caveat that it is based on the human security construct that considers both social and economic vulnerability; like the USAID concept, it reflects the relationship between the state and society.

Vulnerability

Although the 2010 NSS speaks about "at-risk" or fragile nations, the term vulnerability quickly comes to mind when speaking about hazards and is certainly not a novel term in the national security, homeland security, or HADR communities. The United Nations (UN) International Strategy for Disaster Reduction (ISDR) defines vulnerability as the "characteristics and circumstances of a community, system or asset that make it susceptible to the damaging effects of a hazard."[28] In this context, vulnerability is often broken down into various elements, such as physical, governance, social, economic, and environmental hazards, and it is used as part of a larger risk management process.[29]

ILE DE LA GONAVE, Haiti, Sailors assigned to the guided-missile cruiser USS Normandy (CG 60), unload humanitarian relief supplies to a village on the island of La Gonave, Haiti. Photo taken by Ensign Adam R. Cole, February 4, 2010.

The term vulnerability is increasingly used in the context of climate change, though its use in this community diverges from that of HADR practitioners.[30] The Intergovernmental Panel on Climate Change (IPCC) defines vulnerability as "the degree to which a system is susceptible to, and unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate change and variation to which a system is exposed, its sensitivity, and its adaptive capacity."[31,32] An

[28] United Nations International Strategy for Disaster Reduction (UNISDR), Terminology on Disaster Risk Reduction, 2009, http://www.unisdr.org/eng/terminology/UNISDR-Terminology-English.pdf.

[29] O'Brien, K. et al. 2008. Disaster Risk Reduction, Climate Change Adaptation and Human Security. Report prepared for the Royal Norwegian Ministry of Foreign Affairs by the Global Environmental Change and Human Security (GECHS) Project, GECHS Report 2008:3.

[30] Ibid.

[31] UN IPCC, *Climate change 2007*: *The physical science basis*, Report of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (New York: Cambridge University Press, 2007).

example of this is a certain population's vulnerability to natural hazards. Storms of similar intensities can effect different places in vastly different ways depending on how well the community prepares for, and responds to, a given event.[33]

In bridging the gap between security and climate communities, the DoD Minerva-sponsored, Climate Change and African Political Stability Program (CCAPS) has adopted the vulnerability approach and used it as a lens to study climate change's potential linkages with insecurity in Africa. In a 2010 report, CCAPS researchers combined elements of "physical exposure to climate related disasters, household and community vulnerability, governance and political violence vulnerability, and population density)" to develop a macro-level yet geospatially explicit composite vulnerability assessment map.[34] This innovative approach illustrates the interdisciplinary application of a shared concept and its utility for better understanding the connections of climate and environment to fragility, instability, and conflict risks.

For this report, we define vulnerability as a nation, system, society, or community's characteristics, susceptibility, and lack of capacity to absorb, respond to, or recover from a natural hazards or human-made disruptive events.

Resilience

Resiliency can loosely be considered the inverse of vulnerability and fragility. While not a new concept, the adoption and usage of this term has expanded in recent years into several divergent disciplines, in a manner similar to that of fragility. The diversity of definitions and its growing use both challenges its usefulness and helps establish currency across disciplines from ecology to homeland security, HADR, foreign affairs, and, increasingly, climate change. Regardless of the professional community or discipline, the gist of resilience is developing the ability to "bounc[e] back after something bad happens and having the ability to bounce back to [a] better place—a place better suited to new realities."[35]

While more narrowly used, resiliency's diverse conceptual differences are akin to those of security and have gained traction in the national security community, including homeland security, defense, and foreign affairs. What entities need to be

---

[32] Karen O'Brien, et al., *Disaster Risk Reduction, Climate Change Adaptation and Human Security* (Oslo, Norway: University of Oslo, 2008), ISSN: 1504-5749.

[33] USAID, *Climate Change, Adaptation, and Conflict: A Preliminary Review of the Issues*, October 2009, www.usaid.gov/our_work/cross-/cutting_programs/conflict/publications/docs/CMMDiscussionPaper1ClimateChangeAdaptationandConflict.pdf.

[34] Joshua W. Busby et al., Locating Climate Insecurity: Where Are the Most Vulnerable Places in Africa, August 2010, ccaps.robertstrausscenter.org/system/research_items/pdfs/19/original.pdf?1286296660.

[35] Institute for National Security and Counterterrorism (INSCT), Project on Resilience and Security Workshop Report: Resilience in Post-Conflict Reconstruction and Natural Disasters, March 9, 2009, p. 2, insct.syr.edu/uploadedFiles/insct/uploadedfiles/PDFs/INSCT%20Workshop%20Report_Resilience%20and%20Security.pdf.

resilient (infrastructure, governments, economic systems, or communities)? At what level are they to be resilient (global, regional, national, or local)?

For example, in the developing world, substantial populations reside in slums and other peripheral areas that have very limited resilience to natural or human-caused disasters. The United Nations (UN) estimates that the overall risks will become more severe with climate change because “3 to 4 of every 10 non-permanent houses in cities in the developing countries are located in areas prone to floods, landslides, and other natural disasters.”[36] The negative impacts of such emergencies will likely be intensified by the lack of infrastructure, such as potable water, wastewater treatment, reliable electricity, health care and treatment, and other social services that are essential for adequate response operations (examples of limited resilience).[37,38]

OECD offers a definition of resilience that complements that of fragility:

> the opposite of fragility [is] not to be stability, though this has often been the goal of external actors, but rather resilience—or the ability to cope with changes in capacity, effectiveness, or legitimacy.[39]

Although USAID is still in the process of crystallizing its understanding of resiliency, it has affirmed OECD’s assertion that it is complementary to their concept of fragility.[40,41]

From the climate change perspective, the US Interagency Climate Change Adaptation Task Force defines resilience as “the capacity of a system to absorb disturbance and still retain its basic function and structure.”[42] While this definition clearly focuses on the resilience of the US government, its agencies, and its functions, this definitional example raises an important aspect of the concept—whether the intent of “bouncing back” is to the previous state or to one better suited to the current and future environment?

---

[36] United Nations Human Settlements Programme (UN HABITAT), “Cities and climate change adaptation,” paper presented at UN HABITAT Donors Meeting, Seville, 2008.

[37] David Satterthwaite et. al., *Adapting to climate change in urban areas. The possibilities and constraints in low and middle income nations* (International Institute for Environment and Development, 2007).

[38] See Note 33, this chapter.

[39] OECD, Concepts and Dilemmas of State Building in Fragile Situations, 2008. p. 12. www.oecd.org/dataoecd/59/51/41100930.pdf.

[40] USAID, *Conflict, Fragility, and the Environment: A USAID/DHCA/CMM Experts Workshop Summary Report*, May 2011.

[41] See Note 35, this chapter.

[42] Council on Environmental Quality, *Progress Report of the Interagency Climate Change Adaptation Task Force*, National Oceanic and Atmospheric Administration (NOAA), Office of Science and Technology Policy, March 16, 2010, www.whitehouse.gov/sites/default/files/microsites/ceq/20100315-interagency-adaptation-progress-report.pdf.

For this report, we define resilience as the capacity to absorb, respond to, or recover from a natural or human-made disruptive event and thrive in the new conditions. This reflects the ability to cope with a disturbance and retain essential structures and functions. However, it also acknowledges the necessity and relevance of not only developing approaches to build more resilient, less fragile systems, but also moving toward those that are adaptive.

Adaptation

While resilience is the capability to effectively respond to (an acute) disturbance, adaptation concerns the ability or process of adjusting to a long-term (chronic) change from current conditions so as to reduce vulnerability and fragility.

Often cited in the context of climate change, the IPCC defines adaptation as “adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities.”[43]

For instance, adaptation includes the climate-change-related environmental problems that could lead to increased fragility or instability. If adaptation measures are not taken, the likelihood of conflict may increase as human security is eroded and grievances intensify. Environmental change and climate adaptation strategies are necessary at all levels, from internationally funded projects and national government policy to community-level projects and household coping strategies. To the extent that these initiatives build resilience and response capacity, bolster human security, and reduce grievances, they can be instrumental in avoiding climate-change-augmented fragility, instability, or even conflict.[44]

For this study, we define adaptation as the ability to make adjustments that help a society survive and thrive under changing conditions. As defined in this report, adaptation overlaps with resilience, where it involves changes to, or development of, characteristics that enable an entity to better suit new conditions and reduces vulnerability.

REPORT OVERVIEW

Moving forward, this report describes and recommends a framework for organizing data and utilizing knowledge that illuminates the relationships between conflict, instability, and fragility and how they conceptually map to sectors, natural resources, and climate change parameters. To this end, Chapter 2 lays out the study approach, including stakeholder engagement. Chapter 3 discusses the current gaps in data utility and requirements for a transparent architecture. Chapter 4 explores the existing resources for data collection, integration, and analysis. A fragility-based conceptual framework and functional architecture are proposed in

[43] Ibid.

[44] See Note 33, this chapter.

Chapter 5. Chapter 6 focuses on climate change as a threat multiplier to national security and how the proposed conceptual framework and functional architecture could be extended to address climate security challenges. The report concludes with closing thoughts and recommendations for next steps.

Chapter 2
Study Approach

This study consisted of two main efforts: (1) stakeholder outreach and (2) review of conflict, instability, and fragility and natural resource analysis and early warning and enablement capabilities. Throughout the process, we sought to identify and engage Army, DoD, and other government stakeholders, both technical contributors and military mission personnel to explore and identify these concepts' relevance to mission, current needs, and gaps. While doing so, we identified existing data sources and analyses, as well as early warning and predictive capabilities, and assessed their applicability, function, and utility for Army commands, COCOMs, and interagency efforts. This chapter presents our approach to these parallel yet complementary efforts.

STAKEHOLDER AND RESOURCE OUTREACH

We identified and engaged Army, DoD, and other government and non-governmental entities with an interest in analysis approaches and early warning tools for conflict, instability, and fragility as well as the study of their underlying dynamics and relationships to natural resource and environmental factors. The study team initially envisioned an outreach process that would

- include meetings, briefings, and teleconferences to exchange technical information, tools and systems, and mission applications;
- use these engagements to collaboratively develop a common conceptual "operating system" for instability and fragility;
- develop strategic communication products and support additional outreach activities as necessary;
- identify and engage key Army stakeholders and DoD technical resources to be part of an intra-Army working group (IAWG) focusing on instability and fragility early warning and missions supported by such capabilities; and
- identify and reach out to a broader set of government practitioners and technical resources to form an Interagency Forum on Instability and Fragility Assessment, which would include other DoD stakeholders, civilian government agencies, and other stakeholders from academia and the private sector.

Identification

In July 2010, we started compiling an initial list of relevant Army, DoD, and government missions, points of contact (POCs), and technical resources. We leveraged forums and relationships developed during the 2010 AEPI study and encouraged further dialog. For example, we briefed the US Army Corps of Engineers (USACE) Construction Engineering Research Laboratory (CERL) and USAID Office of Conflict Management and Mitigation (CMM) teams working in these areas on the findings of the AEPI *Environmental Factors in Forecasting State Fragility* study, which led to invitations to meetings with access to key thought leaders. The study team specifically participated in the following workshops and conferences:

- USACE/CERL, Proactive Peace Building with Natural Resources Assets: Analysis of Historical Controversies and Conflicts to Inform Future Actions, Chicago, IL, August 18–19, 2010
- AEPI, Using Sustainability to Build Stability: Water Security as an Engagement Tool, Washington, DC, December 14, 2010
- USAID/CMM, Conflict, Fragility, and the Environment: Experts Workshop, Arlington, VA, January 26, 2011
- USACE/CERL, Proactive Peace Building with Natural Resource Assets Workshop #2, Arlington, VA, February 14–15, 2011
- National Defense Industrial Association Environment, Energy and Sustainability Symposium, New Orleans, LA, May 12, 2011
- University of Texas at Austin, Mapping and Modeling Climate Security Vulnerability, Austin, TX, May 16–17, 2011.

In late-2010 and 2011, the team sought to identify Army, external DoD, and government mission stakeholders and technical resources. We compiled Army organizations and POCs into working intra-Army outreach lists and all POCs in a Microsoft Excel contacts database.

Engagement

As stakeholders were identified, the team met with internal Army, other DoD, and external government mission stakeholders and technical resources. Table 2-1 summarizes organizations identified through this effort and their status of engagement (engaged or potential). (Appendix A lists POCs for each of the stakeholder organizations. Appendix B lists meetings held to date.)

These intra-Army, DoD, and government outreach efforts continued for the duration of the study.

Table 2-1. Stakeholder Organizations and Status

Stakeholder organizations	Engaged	Potential
Army		
CAA Force Strategy Division	✓	
USACE CASI	✓	
USACE	✓	
AGC	✓	
HQDA G-2	✓	
HQDA G-3/5/7	✓	
Army Environmental Health		✓
APSI		✓
USACAPOC(A)		✓
USACE Transatlantic Division		✓
National Guard Bureau, Agro-Business Teams		✓
DoD		
USD(P)	✓	
DARPA, Information Processing Techniques Office	✓	
DIA	✓	
Joint Staff, J-2	✓	
Joint Staff, J-4	✓	
Joint Staff, J-5	✓	
AFRICOM, J-2	✓	
SOUTHCOM, J-9	✓	
PACOM		✓
EUCOM, Arctic Domain Awareness		✓
CENTCOM		✓
NGA		✓
DSCA		✓
DTRA (with USDA, CDC, and UN FAO)		✓
Government		
USAID CMM	✓	
CIA Center on Climate Change and National Security	✓	
NASA Headquarters	✓	
Other		
CCAPS University of Texas at Austin & University of North Texas	✓	
University of Illinois at Urbana-Champaign	✓	
University of Maryland CIDCM	✓	
GMU Center for Social Complexity	✓	

Table 2-1. Stakeholder Organizations and Status

Stakeholder organizations	Engaged	Potential
Other		
National Defense University	✓	
iSciences, LLC	✓	

Note: CAA = Center for Army Analysis; CASI = Center for the Advancement of Sustainability Innovations; AGC = Army Geospatial Center; MPICE = Measuring Progress in Conflict Environments; HQDA = Headquarters, Department of the Army; APSI = Army Peacekeeping and Stability Initiative; USACAPOC(A) = US Army Civil Affairs and Psychological Operations Command (Airborne); USD(P) = Office of the Under Secretary of Defense for Policy; DARPA = Defense Advanced Research Projects Agency; DIA = Defense Intelligence Agency, AFRICOM = Africa Command; SOUTHCOM = Southern Command; PACOM = Pacific Command; EUCOM = European Command; CENTCOM = Central Command; NGA = National Geospatial-Intelligence Agency; DSCA = Defense Security Cooperation Agency; DTRA = Defense Threat Reduction Agency; USDA = US Department of Agriculture; CDC = Center for Disease Control; UN FAO = Food and Agriculture Organization; CIA = Central Intelligence Agency; NASA = National Aeronautics and Space Administration; CCAPS = Climate Change and African Political Stability; CIDCM = Center for International Development and Conflict Management; GMU = George Mason University.

These individual and group engagements demonstrated that developing an IAWG and inter-agency forum was premature for the period of performance of this effort. We thus postponed their establishment and convened a smaller Army brainstorming session on April 21, 2011, in Crystal City, VA. We used this focused session to further exchange information with select mission-oriented personnel, frame the broader outreach methods, and plan strategic communications to better promote Army awareness of and engagement in these topics. We then made broader outreach efforts to identify and enlist Army and external stakeholder organizations for the remainder of this study effort, including for the review of the draft version of this report.

Although the IAWG and inter-agency forum were premature, the following subsections summarize the groups envisioned in the midterm.

Intra-Army Engagement

We envision the IAWG mission as promoting an information exchange that supports the development of a common conceptual "operating system" for conflict, instability, and fragility assessments (including natural resource and environmental factor linkages) and exploring its potential contribution to the US Army full-spectrum strategic planning, HADR, SSTR, and mil-to-mil missions. The goals for this IAWG are to

- examine instability and fragility technical approaches;
- evaluate instability and fragility's relationship to mission at all levels;
- solicit end-user questions, requirements, and applications at all levels;

- identify data source and analysis challenges and opportunities; and
- discuss relevant integration approaches for tabular and geospatial data, quantitative-qualitative data, and temporally explicit approaches.

IAWG outputs would be used to develop recommendations supportive of US Army strategic and operational planning, particularly in emerging mission-relevant natural resource (renewable and non-renewable), environmental, and climate shock threat multipliers. (Appendix C contains the draft IAWG charter.)

INTERAGENCY OUTREACH

Where no similar interagency body exists or develops, the study team proposes establishing an inter-agency forum to advance government adoption of a common conceptual "operating system" for conflict, instability, and fragility assessment, the integration of natural resource (renewable and non-renewable) and environmental factors, and the exploration of potential approaches supportive of whole-of-government/interagency efforts. Areas of discussion could include

- existing instability and fragility conceptual and technical approaches;
- common operating system concepts and lexicon development;
- data source and analysis integration challenges, opportunities, and uses;
- integration approaches for tabular and geospatial data, quantitative-qualitative data, and temporally explicit approaches;
- fragility's integration utility for natural resource (renewable and non-renewable) and environmental factors, including climate change;
- gaps and barriers for use or relevance in agencies at all levels; and
- common approaches, key questions, and coordinated demonstrations.

An outgrowth of the IAWG, this forum would provide a structured, yet informal, venue for exchange and discussion, across DoD and civilian government agencies, for sharing concepts, approaches, data, tools, and expertise supportive of whole-of-government/interagency missions. (Appendix D contains the draft Inter-Agency Forum on State Instability and Fragility Approaches and Natural Resources charter.)

EARLY WARNING CAPABILITIES REVIEW

Concurrent with the outreach efforts, we researched and identified hybrid instability-fragility architectures and capabilities, particularly those that can integrate geospatially and temporally explicit approaches. Through our research, we sought to

- expand the analysis of previously identified and relevant fragility approaches supportive of natural resource and environmental factor integration;
- research and map out relevant geospatial data sources for natural resource sectors;
- identify new analysis options (and potential data acquisition streamlining opportunities) relevant to Army proponents and users; and
- examine integration approaches for tabular-geospatial data, quantitative-qualitative data, and temporal approaches.

In addition, our team sought to explore fragility's potential utility for meaningfully integrating climate change drivers. We first examined fragility, natural resource sector, and climate change conceptual compatibilities and differences. We then performed an initial natural resource sector and environmental factor crosswalk against broad climate regime impacts. We had hoped to review and leverage the pending findings of the 2010–11 Defense Science Board Task Force on Trends and Implications of Climate Change for National and International Security, but these were not yet available at the time of drafting this report.

To achieve these aims, we undertook the following research approaches and methods focusing on data, analysis, tool, and system options available.

Data Search and Selection

To identify and catalog relevant nation-state-level tabular and geospatial data resources, we used an expanded literature search to identify further data libraries, statistical databases, and indexes that focus on energy, natural resources, environmental factors, international development, and sustainability. We first revisited resources identified for the 2010 AEPI study, with an expanded focus on geospatial resources. Building on these efforts, our researchers supplemented these data clearinghouse reviews with topical web searches to identify more narrow, specialty data sources. During the course of this study, we identified, vetted for relevance, and cataloged promising energy, natural resource, and environmental factor data sources in a searchable and sortable Microsoft Excel database. To the extent possible, this database captures basic information on the data or indicator, spatial and temporal attributes, source, availability, and reference links to the respective data resources. (Appendix E contains the catalog.)

Analyses Modes

While identifying data resources, we sought to pinpoint different analytical techniques used in assessing, modeling, predicting, and understanding conflict, instability, and fragility. Again, we first reviewed previously identified technical information and reports on the current analysis, models, and tools available.

Second, both the data research and outreach teams tried to capture relevant conflict, instability, fragility, and social vulnerability analysis approaches, which were subsequently categorized. These analysis buckets were developed to cover and represent the wide range of analysis techniques used for assessing conflict, predicting instability, and describing fragility and social vulnerability. Third, we captured examples of relevant data collection (remote sensing), analysis efforts and approaches and developed profiles as examples of the different categories (Chapter 4, Appendix F, and Appendix G). Finally, we collected pertinent information for categorizing approaches, including the types of data inputs and outputs, resolution and coverage, analysis complexity, time scale, software support needed, and whether or not the tool was or is being integrated with other conflict or fragility tools and systems. We used this information to create summary tables (Chapter 4 and Appendix G).

Tools, Systems, and Output Products

In addition to identifying data sources and analysis modes, we researched and reached out to Army, other DoD, government, and academic leaders to identify existing and emerging conflict, instability, and fragility early warning systems, particularly those with capabilities to incorporate natural resources and environmental factors. To this end, the team first sought to identify capabilities cited in known instability and fragility reports, recommended by subject matter experts (SMEs) or tool designers or affiliates, and via supplemental web searches. Several tools and systems are deemed “sensitive but unclassified,” but the majority have some form of published technical write-up that specifies purpose, inputs, methods, analyses, and outputs.

We relied on technical publications and articles to compile standard details about the conflict, instability, and fragility early warning tools and systems. Supplemental information from by technical stakeholders, when available, was used to augment these profiles. These profiles were used to assess their respective strengths, weaknesses, and possible opportunities for integration with other related capabilities. Chapter 4 provides examples of the different categories of analyses, tools, and systems. Appendix G contains one- or two-page summaries for each of the most relevant tools and systems. Chapter 5 summarizes the output products we identified and used to inform the proposed early warning framework and architecture.

Chapter 3
Mission and Fragility, Capabilities, and Gaps

During the course of this study, we sought to identify the intersection of Army and DoD missions and fragility, emerging capability needs, and technical gaps associated with conflict-instability-fragility and natural resource analysis and early warning. We asked stakeholders to identify relevant missions and their needs. Three military missions were identified where fragility is a consideration: SSTR, HADR, and mil-to-mil engagement. We also reviewed and expanded on the gaps cited in 2010 AEPI study.[1] In this chapter, we present the findings to date on Army and DoD mission needs and summarize the identified technical gaps.

MISSION AND FRAGILITY

Joint doctrine addressing stability operations sets the foundation of user needs for fragility early warning capability. Its definition of stability operations captures the role of military forces to support broader governmental efforts:

> [Stability operations encompass] various military missions, tasks, and activities conducted outside the United States in coordination with other instruments of national power to maintain or reestablish a safe and secure environment, provide essential governmental services, emergency infrastructure reconstruction, and humanitarian relief (JP 3-0).[2]

The importance of stability operations in an era of persistent conflict became increasingly clear following the start of combat operations in Afghanistan and Iraq. Recognizing this shift, DoD implemented DoDD 3000.05 in November 2005. The directive emphasizes that stability operations are no longer secondary to combat operations, stating the following:

> Stability operations are a core US military mission that the Department of Defense shall be prepared to conduct and support. They shall be given priority comparable to combat operations and be explicitly addressed and integrated across all DoD activities including doctrine, organizations, training, education, exercises, materiel, leadership, personnel, facilities, and planning.[3]

---

[1] AEPI, *Environmental Factors in Forecasting State Fragility*, June 30, 2010, www.aepi.army.mil/.

[2] Headquarters Department of the Army, FM 3-07, *Stability Operations*, October 6, 2008.

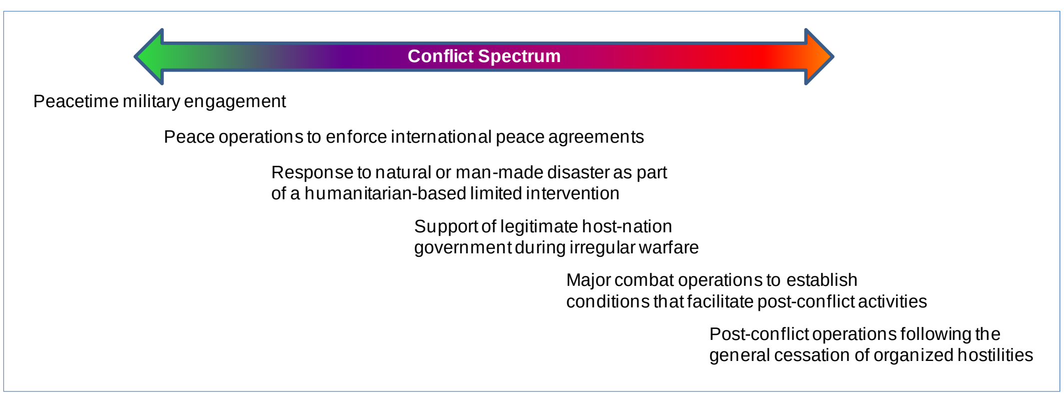
[3] Ibid.

Army FM 3-07 addresses military stability operations in the broader context of government reconstruction and stabilization efforts. It describes the role of military forces in supporting those broader interagency efforts by leveraging the capabilities of the force to establish a safe and secure environment; facilitate reconciliation among local or regional adversaries; establish political, legal, social, and economic institutions; and help transition responsibility to a legitimate civil authority operating under the rule of law. This is fundamental to the shift in focus toward long-term developmental activities where military forces support broader efforts in pursuit of national security objectives.[4]

KABUL PROVINCE, Afghanistan – A US Army Soldier hands out 5-kilogram bags of flour to local Musahi villagers, Monday. The humanitarian aid mission was a joint ANP and coalition effort to provide blankets, jackets, ear muffs, gloves, socks, cooking oil, rice, beans, sugar, and flour—enough to help 500 families. (Photo taken by US Army, February 1, 2011.)

Any integrated approach to stability operations requires a framework that applies across the spectrum of conflict, from stable peace to general war, reflecting the execution of a wide range of stability tasks performed in various operational environments. Figure 3-1 shows some of the stability mission requirements from which specific user requirements for fragility early warning systems stem. To be effective, such systems must provide the necessary data and analytical capabilities to support corresponding analysis, planning, and execution of those efforts.

Figure 3-1. Stability Mission Requirements



Source: Adapted from FM 3-07, *Stability Operations*, October 6, 2008.

[4] Ibid.

Effective, accurate, and timely intelligence and situational awareness are essential in full-spectrum operations, especially in stability operations, where the success or failure of the mission often depends on the effectiveness of the intelligence effort. In operations among a civilian population, tailored intelligence facilitates understanding of the operational environment while emphasizing the local populace, host nation government, and state security apparatus.[5] Fragility early warning—in particular, that which incorporates environmental and natural resource factors—may provide a broader perspective of indicators earlier in the conflict spectrum to support the intelligence needs in-theater.

NEEDED CAPABILITIES

Army analysts and decision makers require the capability to access and assess information resources to better understand the relationships between fragility, its components, and natural resources. Building on identified needs and capabilities, an approach, tool, or system should help users identify and retrieve relevant quantitative and qualitative information from existing data streams. It will aid in data analysis, generate tailored knowledge products, and help practitioners explore underlying dynamics and relationships germane to planning for, or reacting to, situations in fragile states.

First, the way an analyst structures specific research questions drives the capability to understand a situation. One value of fragility is that it can help frame potential relationships and dependencies among concepts such as conflict, instability, human activity sectors, and natural resources. Second, once the mission-relevant questions are framed, analysts must be able to query multiple quantitative data sets and leverage qualitative sources to rapidly locate and organize the relevant information. Optimally, any tool or system will help by intelligently recommending queries and data sources, analyzing relevant data, and generating initial output in the form of raw data, reports, graphs, and mapping products. Analysts can improve the data sets by adding their expertise and experience to the data and their analysis, which can be captured in some systems. Third, any such systems should help analysts synthesize the tool’s outputs and draw conceptually grounded conclusions. Finally, capabilities should help analysts prepare and display their results in a product accessible to Army planners and decision makers and understandable enough for them to take action (which instability lists often aren’t). Based upon input from stakeholders, Table 3-1 summarizes potential user needs for analysis, early warning, and enablement capabilities identified to date.

[5] Ibid.

Table 3-1. Needs for Capabilities

Functionality	◆ Support the analysis, planning, and execution of stability mission requirements (Figure 3-1) ◆ Augment existing Army early warning and scenario planning tools ◆ Reduce the time and effort to generate response strategies ◆ Provide situational awareness ◆ Improve visibility and understanding of non-traditional threat areas ◆ Identify and suggest potential relationships and dependencies between instability, fragility components, sectors, and natural resources ◆ Monitor fragility indexes ◆ Identify peace-building opportunities ◆ Assess strategic opportunities (such as counter-insurgency) ◆ Support capability assessment ◆ Support collaboration and partnering (for both information exchange and broader engagement purposes) ◆ Enhance operational effectiveness
Accessibility	◆ Data accessibility approach will determine its utility ◆ Classified or for official use only (FOUO) efforts will continue to serve classic defense functions, such as national intelligence estimates (NIEs) and threat assessments ◆ “Open source” has a greater potential utility for engagement
Flexibility	◆ Support various levels of users from headquarters to field ◆ Tailor the research to fit the situation ◆ Improve the data sets by adding notation/qualitative data
Compatibility	◆ Have a lexicon compatible (within the Army and to outside government) to recognize the value ◆ Use or relate to existing sources of qualitative and quantitative information resources
Content	◆ Expand fragility indexes to include natural resource sectors and environmental threats, such as climate change (in addition to security, political, social, and economic factors)
Outputs	◆ Identify areas and sources of additional information that are potentially relevant ◆ Synthesize data and information to support supplemental research and decision making ◆ Output the results of these queries in the form of raw data, reports, graphs, and mapping products

As future outreach efforts expand within the Army and DoD, and across government agencies, the scenario applications, objectives, and specific capability needs will likely expand but also be further refined to better align with specific organization and mission needs and their core operational and strategic questions. Analysis of the specific needs of HQDA, Army commands, COCOMs, and other Army organizations operating in roles ranging from peacetime engagement to in-theater combat operations would address accessibility and other capabilities that enhance those functions as well as identify the background and skills needed by analysts (such as water specialists for USAFRICOM).

BAMAKO, Mali - Malian soldiers conduct fast rope operations out of a MH-47 Chinook helicopter from the US Army's 160th Special Operations Aviation Regiment (Airborne) in Bamako, Mali May 18, 2010. The military training engagement was part of an AFRICOM-sponsored exercise called Flintlock 10, a special operations forces exercise focused on military interoperability and capacity-building with partner nations in northern and western Africa. Photo by US Air Force Technical Sergeant Marelise Wood, Flintlock Public Affairs.

PREVIOUSLY IDENTIFIED TECHNICAL GAPS

The 2010 AEPI study identified gaps in information and resources for fragility analysis and monitoring,[6] particularly those associated with the consideration of natural resource and environmental factors. Gaps associated with geospatial data create challenges for analyzing fragility and environmental change. These include access to data, incomplete metadata, and variations in the spatial coverage, accuracy, frequency, methods, and compatibility of the data. We detail these gaps in the following subsection.

Geospatially Explicit Data and Analysis

Current instability risk and fragility index approaches are not geospatially explicit past the national level. This is problematic as current fragility approach resolution can vary in size from Haiti to China. Fragility's domains (including environment) apply to community- and even local-level dynamics, so fragility data collection, analysis, and integration approaches would benefit from disaggregated and higher resolution data sources, particularly when considering natural resource and environmental factors, which are more localized in their interaction with the human terrain.

[6] See Note 1, this chapter.

Geospatial data are available in all shapes and sizes. This diversity of spatial extent and resolution affects the alignment of data sets and their respective layers. When the coverage varies, researchers must exclude certain areas from their analysis or analyze less precisely. This limitation is common in global data sets because many countries lack the resources to collect primary data, so consistent data availability is a challenge, particularly at finer-scale resolutions.[7]

Scale is useful in characterizing biophysical processes and a key attribute in making any data or approach geospatially explicit. Although structural statistics can be disaggregated and defined by scale, they can be impacted by both "random and systematic errors."[8] Stakeholders in the 2010 AEPI study cautioned that disaggregated national statistics can reflect heavy biases.[9] While disaggregated data sources (when available) and their analysis have pitfalls, greater flexibility with scale is needed to open new analytical opportunities, particularly for understanding the bidirectional relationships between natural resources, fragility, and conflict.

As natural resources are often concentrated in specific locales or regions, resultant tensions or conflict dynamics are not likely to be manifest at a national level, at least not initially. Research suggests that natural-resource-related conflicts may center on specific resource types and locations,[10] so subnational, geospatially explicit data sets would appear necessary in developing an accurate understanding of the underlying dynamics and the appropriate, effective peace-building mitigations.

Temporally Explicit Data and Analysis

As noted in the 2010 AEPI study, many of the historical conflict analysis, instability risk models, and fragility index approaches operate using an annual update frequency or "time step." [11] Annual updates are often appropriate for strategic analysis and decision making, but they are often not as directly useful for COCOM operational-level planning.[12] One example of an operational early warn-

[7] The lack of finer scale data is a challenge, but this does not prevent meaningful research and analysis. In the near term, data interpolation techniques are possible stopgaps measures at a given scale of analysis. For example, Oak Ridge National Laboratory's LANDSCAN population estimates utilize interpolation techniques to extend the analysis past the limited resolution of available satellite imagery.

[8] Javier Fabra Mata (DIE) and Sebastian Ziaja (UNDP), Users' Guide on Measuring Fragility, www.carleton.ca/cifp/app/serve.php/1245.pdf.

[9] See Note 1, this chapter.

[10] Gilmore et al., Conflict Diamonds: A New Dataset, Conflict Management and Peace Science, Volume 22, Issue 3, 2005, 257–272.

[11] See Note 1, this chapter.

[12] Although annual time steps may not be as directly applicable for monitoring and early warning systems, historical studies using annualized data could yield highly useful insights into relationships between conflict, instability, fragility, and natural resources. These conceptual insights may offer a richer understanding and have relevant input for analysis and decision makers on the most appropriate, cost- and resource-effective efforts.

ing architecture is the Famine Early Warning Systems Network (FEWS-NET), which generally operates on a monthly time step. These temporal aspects can be a significant factor in the relevance and utility of data, analysis, and integration architectures.

Not only is the frequency key, but the data collection time lags. For instance, structural statistics' usefulness is impacted by time delays in their update cycles. In particular, geospatial data sets greatly vary in their frequency of collection and reprocessing. This temporal and status component can dictate a reliance upon certain types of data acquisition and analysis architectures, particularly for real-time monitoring.

Geospatial data sets are also prone to the challenge of "one off" products. Researchers may prepare and process data for a one-time project and not intend to provide additional analyses in the future. Alternatively, they may also collect data irregularly or in multiyear cycles. For applications where monitoring or early warning is central, such as weather and natural hazard warning systems, hourly, daily, monthly, or annual data collection intervals are more the norm.

Temporal challenges must be considered regardless of the intended data usage, whether for historical analysis and exploratory models, early warning systems, or predictive tools. Likewise, these considerations as just as driven by the questions and purpose they are being leveraged to address.

Data Accessibility, Usability, and Utility

Availability

Access to data is very important—no inductive analysis is possible without it. Open-source clearinghouses and data libraries tend to provide easy online web access. Some require free user registration to download data; others work on a subscription basis or allow authorizations only for specific uses. However, not all data sets are available. For instance, all the data cannot be accessed in some cases because sources limit the amount of data shared or make data viewable only through a web-based mapping tool, which limits exportability.

Accuracy

Incomplete—or, worse, inaccurate—data create uncertainties about the data set and their subsequent analysis and outcomes. This ultimately affects the accuracy of predictive and exploratory capabilities. Such errors often result from poor initial measurements, poor quality assurance and quality control efforts, human error, or changes in collection methods over time.

Data Incompatibility

Data compatibility affects our ability to share and join data. The data typically encountered have different format languages that may not combine well with other data types in their original form. These challenges result from the creation of specialized data standards that protect or promote a specific data format or, in some cases, from an absence of data standards altogether.

Method Consistency

Differing methods are in use to process and aggregate primary and secondary data. This lack of consistency can make comparison of different data sets challenging. For instance, data manipulation methods may not use the same logic or assumptions or may give more weight to one item than another. Also, the data collection and coding may be more fundamental in that the concept being quantified has a unique definition, such as that of conflict, instability, or fragility (Chapter 1).

Integrated and Triangulated Fragility Approaches

The 2010 AEPI study cited several instability and fragility approaches that solely use or combine qualitative expert or content analysis approaches. Differing analysis cultures among US agencies can complicate aligning and combining complementary qualitative approaches with quantitative data acquisition, analysis, and decision-making processes to accurately inform government smart power plans and efforts—but the effort is one worth undertaking. For example, Dr. Jack Goldstone has made the case that complementary usage of quantitative (data-driven) instability risk models and qualitative (expert-based) "structural analogs" can significantly increase their accuracy.[13] Such hybrid approaches can potentially increase the confidence of early warning by maximizing when the independent methods agree (data "triangulation").[14] Thus, integrated concepts, analysis, and findings can provide red flags or contextual information when the results disagree. For example, the US Intelligence Community already uses data triangulation as a foundational method in its information quality ratings.

The potential in blending qualitative and quantitative approaches extends further than improving accuracy. It relates back to the challenge of differing government organizational and analysis community cultures. For example, to address these differing approaches and facilitate and coordinate whole-of-government approaches to conflict, the Department of State developed the Interagency Conflict Assessment Framework (ICAF) to facilitate the blending and ground truthing of dynamics and actors in a conflict environment. Any potential analysis

[13] Jack Goldstone, *Special Report: Using Quantitative and Qualitative Models to Forecast Instability* (Washington, DC: United States Institute of Peace, 2008).

[14] Bruce Berg, *Qualitative Research Methods for the Social Sciences*, sixth edition (Boston, MA: Pearson, 2006).

and early warning system must be able to address the challenges of blending quantitative and qualitative approaches in an integrative and transparent manner.

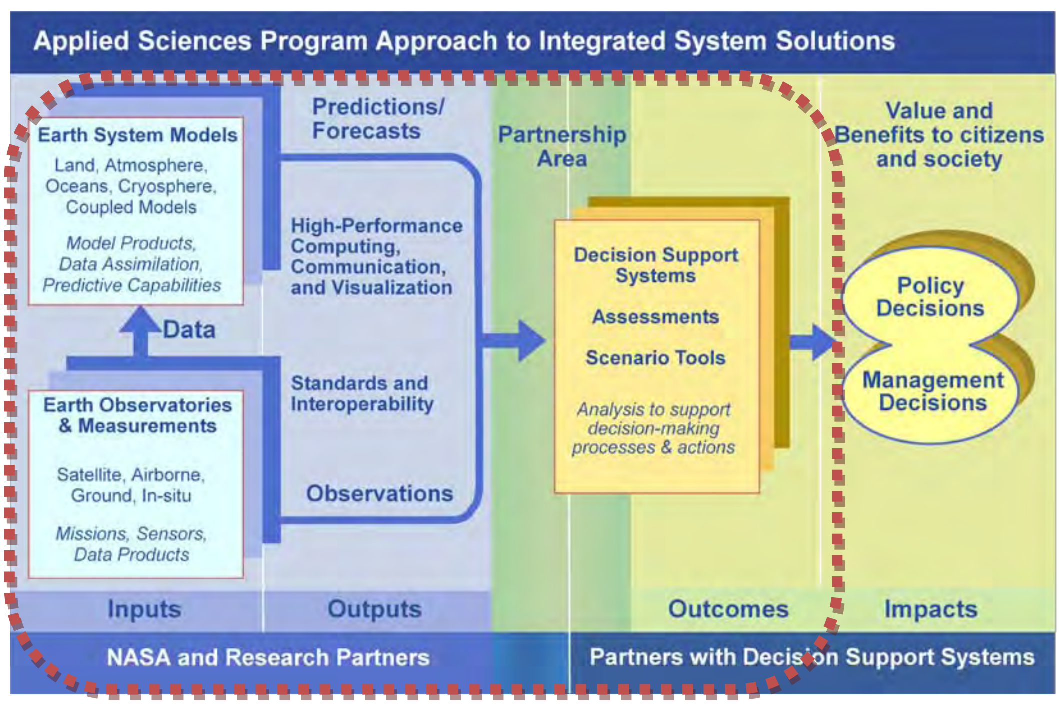
Although much of this report focuses on quantitative resources and analysis, the deductive reasoning and qualitative study cannot be understated in its role for developing a better understanding of the relationships between conflict, fragility, and natural resources. The underlying dynamics between conflict and natural resources have been much studied, but these complex relationships are still being explored. However, understanding these subtle relationships is necessary for making early warning and predictive tools more actionable by developing sufficient understanding to diffuse the situation rather just reacting. Recognizing conflict, instability, fragility, and vulnerability is the first step, but developing a greater understanding of the underlying relationships to natural resources and environmental change can also produce actionable opportunities for adapting and increasing resiliency.

Chapter 4
Resources and Capabilities

As introduced in Chapter 2, this study initially focused on identifying the relevant and available geospatial data sources for natural resource sectors and conflict-instability-fragility capabilities. Throughout our research, we built on the 2010 AEPI study of previously identified and relevant fragility approaches and natural resource and environmental factor integration approaches. We compiled relevant temporally and geospatially explicit data resources. In addition, the outreach process identified conflict, instability, and fragility analysis, model, tool, and system options that could be relevant to Army, DoD, and government users in efforts to develop robust analysis and early warning architectures.

Conflict, instability, and fragility approaches have historically centered on the state- or country-level object of reference and use tabular statistical panel data. However, emerging armed and social conflict research is now being analyzed at the subnational-level using geocoded, disaggregated data and techniques.[1]

Figure 4-1. Study Data to Decision Support Category Approach



Source: Lawrence Friedel, "NASA Applied Sciences Program: Decision Support through Earth Science Research Results," October 30, 2007, presentation to the Cooperative Ecosystem Studies Unit (CESU) Network Council Meeting, Applied Sciences Program, Science Mission Directorate, National Aeronautics and Space Administration (NASA) Headquarters, 2007.

[1] Clionadh Raleigh, "Scales of Conflict Research," International Studies Association Convention, Montreal, March 16, 2011.

Thus, we focused our efforts on identifying the respective geospatial data source, classification, and integration approaches; analysis modes; modeling techniques; and output products as well as the relevant capabilities available to the Army, DoD, and other government agencies. In this chapter, we provide findings on the identified data; classification, integration, and monitoring; analyses modes; models and tools; and frameworks and early warning systems, particularly in the context of better understanding the relationships between conflict-instability-fragility, vulnerability, resilience, natural resources, and environmental change.

DATA

The United States, in addition to other space-faring nations, has been collecting geospatial data via remote sensing of the Earth's surface for decades. In the past, remote sensing data have not been a primary data source for social scientists, particularly those studying conflict, instability, and fragility. Now, however, together with their geoscience colleagues, they are increasingly realizing their importance and utility.[2] For this study, we identified nearly 200 data resources on energy, natural resources, and human-sector interactions with the environment, particularly those that could relate to fragility, instability, and conflict. In going through this process, we identified key aspects, data types, and data providers in these areas. In addition to our summary findings, we developed a working index of data sources and providers (Appendix E).

Data Aspects

Until recently, conflict, instability, and fragility data sources have primarily focused on the national scale (or nation-state object of reference or study focus), while natural resource and environmental factor data are much more granular, reflecting local conditions. Country-level data are often appropriate when speaking about geopolitics or state-to-state relationships, but this fixed scale becomes inadequate to robustly explore the interactions between fragility and natural resources and environmental factors, particularly as they are usually unaffected by nation-state boundaries. Fragility's broader applicability makes it necessary to understand the characteristics and implications of scale, domain, and time step.

SCALE (RESOLUTION AND EXTENT)

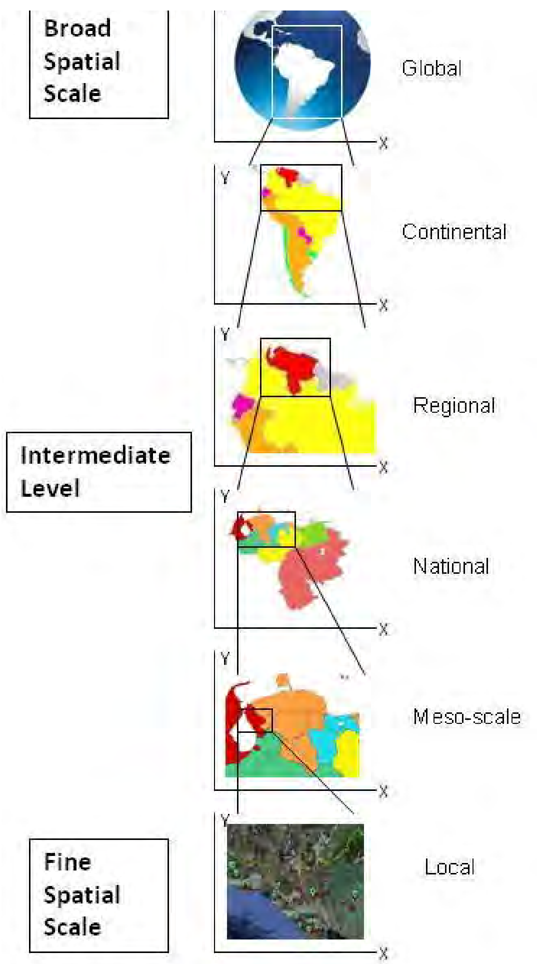
The spatial scale of data sources varies in resolution and extent. Resolution refers to the spatial or temporal scale used to present the data, and extent refers to the total geographic area the data cover. Spatial resolution is particularly important when dealing with geospatial data sets (see the discussion of vector shapefiles and raster images below).

[2] Liverman et. al., ed., Committee on the Human Dimensions of Global Change, National Research Council, *People and Pixels: Linking Remote Sensing and Social Science* (Washington, DC: National Academy Press, 1998).

For example, in a raster data set, the spatial resolution is the size of the grid cells that make up the full extent of the data set. Raster data with high resolution comprise grid cells that represent a smaller area (a 2 × 2 m cell), while the grid cells of lower resolution raster data cover a larger area (a 2 × 2 km cell). Temporal resolution—the shortest unit of time used to represent a data set—is also an important consideration in combining diverse sources of data in this functional architecture. For example, a quantitative environmental data set that measures the concentration of carbon dioxide in the atmosphere may contain daily measurements, whereas a data set that measures lost acreage in a forest may have monthly or annual ones. Temporal extent, which also varies between data sets, is the total relevant time the data set covers.

As discussed in the 2010 AEPI study, current instability and fragility approaches are not geospatially explicit past the national level. This is problematic because fragility approach resolution can vary in size from the Vatican City to the Russian Federation. Figure 4-2 illustrates scale definable levels.

Figure 4-2. Levels of Geospatial Scale



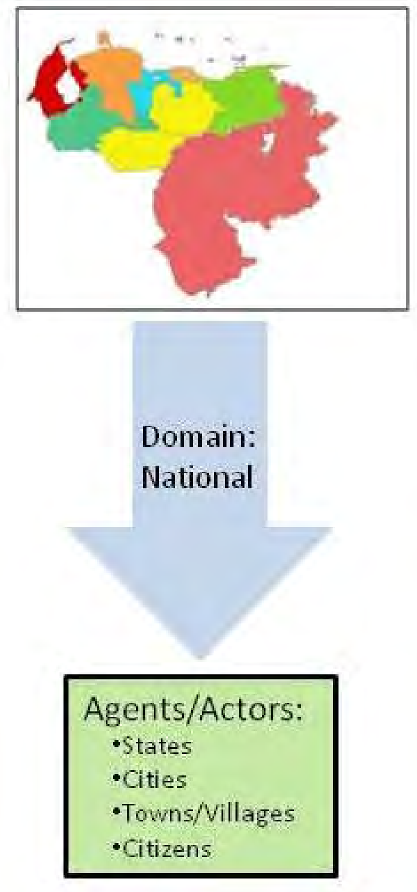
Scale is a key attribute in characterizing biophysical processes and in making any data or approach geospatially explicit. Natural resource and environmental factors are effectively local, but much of the available data are gathered from remote sensing platforms.[3]

Domains

Fragility's domains (including environment) have many disaggregated local- and community-level dynamics, so any alternative data collection, analysis, or integration architecture used should define resolution to the extent possible.

[3] Chetan Agarwal, et al., *A review and assessment of land-use change models: dynamics of space, time, and human choice*, General Technical Report NE-297, US Department of Agriculture (USDA), 2008, www.nrs.fs.fed.us/pubs/gtr/gtr_ne297.pdf.

Figure 4-3. Analysis Domains



Temporal and spatial scales apply well to many types of data, especially geophysical measurements. However, they do not apply well to data regarding human decision making. Social scientists classify human decision-making data in terms of agents and domains. Agents refer to the actor or actors making decisions, such as an individual or village. Domains refer to the widest social organization incorporated in the data, for example, a nation or region (Figure 4-3). For example, much of socioeconomic statistical data focus on individual or household agents at a state domain level.[4]

Domains can be further broken down into physical and virtual domains. Physical domains, such as neighborhoods or cities, are constrained and influenced by physical distance phenomenon. Virtual domains, such as online social networks, are unhindered by physical distance. The rise of virtual domains over the past decade has empowered widely dispersed people to communicate, share ideas, and interact.[5]

TEMPORAL ATTRIBUTES

Data sets vary widely in terms of the frequency of collection and duration of their data. Those updated more frequently allow for more accurate analysis. Frequently updated data also improve relevance and applicability (operational or strategic usefulness) because temporal data gaps and short collection histories limit usefulness for consistent and long-term trend analysis. The duration or time step of the data determines the ability to monitor changing conditions over time.[6]

Data time step or collection frequency needs to be considered in any discussion of fragility, natural resources, environment, and climate. For example, most, if not all, conflict, instability, and fragility models use an annual time step. This time scale seems appropriate for strategic awareness but may be less useful for regional COCOM planning. An example of an operational early warning architecture is the FEWS-NET, which, in most cases, operates on a monthly time step. This temporal characteristic can dictate a reliance on certain types of data acquisition and analysis architectures. When analyzing multiple environmental data sets simulta-

[4] Ibid.

[5] Ibid.

[6] Ibid.

neously, reviewing their respective collection frequencies and durations is important. Analyzing data sets with wildly varying frequencies or durations may lead to inaccurate or misleading analytical conclusions.

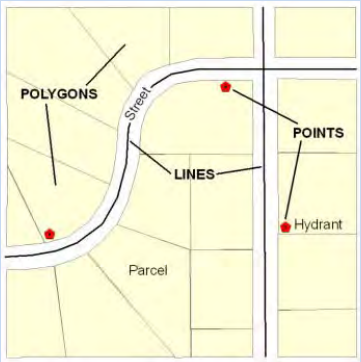
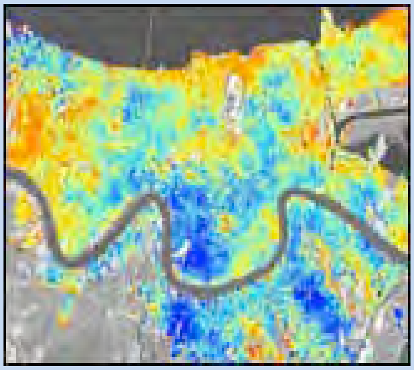
Data Types

As discussed in the 2010 AEPI study, many instability and fragility approaches are characterized by their respective data acquisition methods. Their data sources fall into various categories, such as statistical data, opinion data (surveys, focus groups, etc.), content capture and analysis, and expert data.[7] We found energy, natural resource, and environmental factor data are available in six general, but non-mutually exclusive, forms: geospatial, remote sensing, national statistics, event/media data, qualitative (interview/survey), and unstructured data. Our data identification efforts primarily focused on geospatial data, but we found that each of these data types renders information useful in understanding energy, natural resource, and environmental interactions with fragility dynamics (security, political, economic, and social). We elaborate on each category below.

Geospatial data are information referenced to locations on the Earth. To produce geospatial data, researchers join data elements with geographic location attributes. This alignment with spatial characteristics makes geospatial data useful for depicting and analyzing a range of data and information. Vector and raster are the most common types of geospatial data (Figure 4-4).

[7] Javier Fabra Mata (DIE) and Sebastian Ziaja (UNDP), Users' Guide on Measuring Fragility, www.carleton.ca/cifp/app/serve.php/1245.pdf.

Figure 4-4. Vector and Raster Formats

Vector data formats use polygons, lines, and points to represent areas and features in space. The common vector data format is a shapefile, which is useful for representing boundaries or river systems and illustrating nation-state metrics.  Source: M. Hagerman, Dakota County Office of Geographic Information Systems, 2006, www.co.dakota.mn.us/Departments/GIS/Newsletter/Winter2006_GIS101_raster_faster.htm.	*Raster* data formats differ in that an area of space is subdivided into cells of equal size, each representing a specific value. The models produce text-based raster data formats to represent satellite imagery of vegetation and weather forecasts, digital elevation maps, and land use changes from remote monitoring.  Source: NASA, Earth Observatory, Subsidence in New Orleans, June 3, 2006, earthobservatory.nasa.gov//IOTD/view.php?id=6623.

Remote sensing platforms and sensor technologies are often the core of geospatial data and systems. Remote sensing is a process of gathering spatially organized data from a remote location by sampling signals of electromagnetic radiation that emanate from a specific source target. Interpreting these signals can reveal information about objects, features, and classes on the different surfaces of the Earth.[8] Many devices or sensors can receive these radiation signals, such as recording cameras, radiometers, scanners, radio frequency receivers, radar systems, sonar, and lasers.

As a process, remote sensing involves several necessary components, including

- a target or sensed scene,
- a platform for sensors and instruments,
- a sensor that emits or receives the electromagnetic radiation,
- a signal of electromagnetic energy emanating from the scene or target,

[8] NASA, "The Concept of Remote Sensing; Sensors," Accessed 23 June 2011 at http://rst.gsfc.nasa.gov/Intro/Part2_1.html.

- data processing and intermediate products, and
- data compilation, integration, and visualization.

User requirements largely determine the area or target to be sensed. Data needed to inform research conducted in different sectors, such as agriculture, forestry, geography, and hydrography, require targeting different land attributes. Targets or scenes could be as small as centimeter-diameter lased point or as large as captured visual spectrum images of an entire planet.

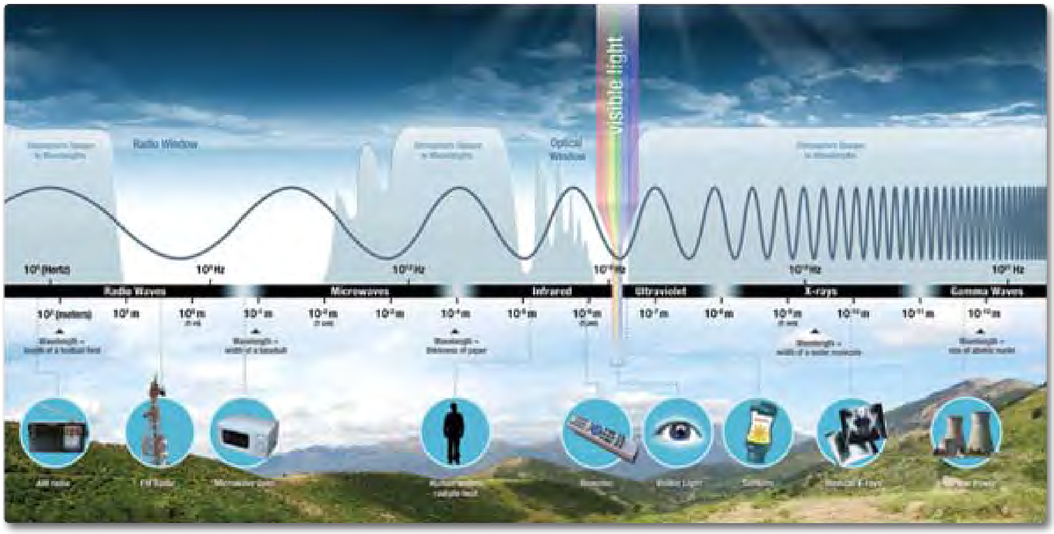
A large variety of platforms are used in remote sensing, such as aircraft, balloons, satellites, spacecraft, probes, rovers, and launch vehicles. In particular, satellite platforms have significantly contributed to global and regional Earth surveys. Those such as the Landsat series have provided a nearly continuous global record of surface change, with images and data dating back to the 1970s.[9] Other remote sensing platforms and sensors can be used as standalone information sources or to augment satellite data. Aerial photography taken from planes, helicopters, and unmanned aerial vehicles has furnished valuable visual and sensor information to the US military for decades.

Platforms do not, however, generate data. Their onboard sensors perform this function and are defined by several characteristics, such as their electromagnetic (EM) spectral properties (Figure 4-6). Sensors function by intercepting an EM waves. Target objects and materials selectively emit or absorb radiation frequencies across the entire EM range. In general, sensors fall into two categories, panchromatic (single band) and multispectral (multiple bands), which can measure reflected energy in different, discrete portions of the spectrum, producing separate images referred to as bands or channels.[10]

[9] USGS, "The Future of Landsat," 2010.

[10] CIESEN, "A CIESEIN Thematic Guide to Social Science Applications of Remote Sensing," October 2002.

Figure 4-5. Electromagnetic Spectrum



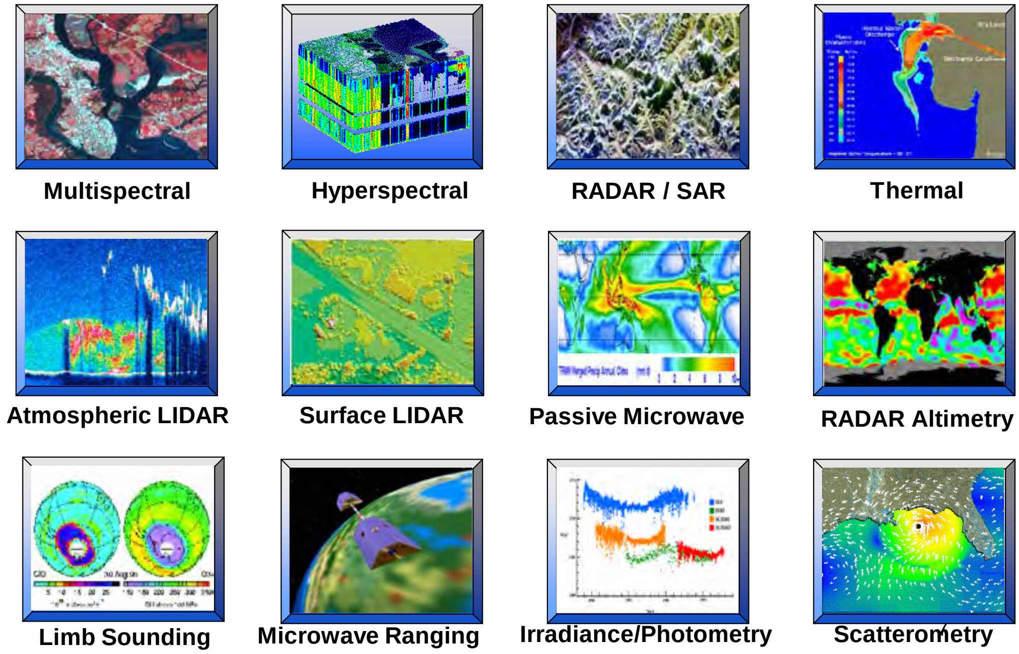
Source: NASA, Mission Science, Introduction to the Electromagnetic Spectrum, http://missionscience.nasa.gov/ems/01_intro.html.

> **Example: MODIS**
>
> Moderate Resolution Imaging Spectro-Radiometer (MODIS) is a medium resolution multispectral radiometer that achieves complete global coverage every 1 to 2 days. Currently installed on the AQUA and TERRA satellites, MODIS observes a range of environmental parameters such as vegetation and land cover, cloud and aerosol properties, and sea ice cover, which all contribute to a greater understanding of climate change dynamics.

A second key sensor characteristic is altitude and path. Sensors that are geostationary are installed on satellites placed at very high altitudes (about 36,000 km above the equator). Sun-synchronous or polar-orbiting sensors are mounted on satellites placed much closer to the surface of the Earth (700 to 1,000 km) and often orbit in the direction opposite of the Earth's rotation. The third characteristic is swath width, which is the total area surveyed by the sensor. The fourth is spatial resolution, which can be as low as 0.6 to 10 meters as is common in commercial high-resolution sensors on satellite platforms. The sensor resolution influences the detail with which an image can be processed, analyzed, and viewed.[11] Satellite-based sensors generate a host of data at various resolutions (Figure 4-6).

[11] Ibid.

Figure 4-6. Remote Sensing Technologies



Source: Lawrence Friedl, "NASA Applied Sciences Program: Decision Support through Earth Science Research Results," presentation to the CESU Network Council Meeting. Applied Sciences Program, Science Mission Directorate, NASA Headquarters, October 30, 2007.

The scope of remote sensing data to monitor and analyze natural resources and environmental factors and their roles in fragility, instability, and conflict is a vast challenge and opportunity. Compiling relevant images, measurements, and readings over long periods to produce relevant outputs and end-products requires extensive processing, integration, and visualization capabilities. We identify some readily available geospatial data resources and details on remote sensing processes and capabilities in Appendixes E and F, respectively.

National statistical data represent observations of elements within a country, including economic production, such as gross domestic product (GDP), and resource stock, such as acres of agricultural or forest land. The 2010 AEPI study explored and elaborated on many of the relevant resources. In general, these data are often numerical sums available as tabular nation-state scale data in comma-separated values (CSV) and Microsoft Excel file formats.

Media or event data comprising captured articles and distilled coding results from journalistic reports or broadcast summaries of historical (human and software algorithm coding coding) or even current events (algorithm coding). These news reports and their derived data can record useful conflict event

Example: SPEED

Social, Political, and Economic Event Database (SPEED) was developed by the Cline Center for Democracy at the University of Illinois. This capability leverages and codes media reports from the British Broadcasting Corporation (BBC). These coded data are then can be analyzed to identify trends and linkages, for example, the linkages between natural resources and conflict.

information at the subnational- and local-levels. They can also be used to provide early indications of conflict and instability through approaches such as sentiment analysis. Researchers are already geotagging captured articles for geospatial analysis purposes, and these metadata can help in tracking the frequency or severity of events.

Qualitative data result from many techniques, including surveys, interviews, review boards, and content analysis. Interviews with SMEs and survey data compilations can capture public or subgroup opinions at a given point in time. This can be useful when trying to assess past dynamics but are not as helpful in developing future predictions. However, the analysis of content such as policy documents or anthropological studies can provide keen insights into a situation and its causes that cannot be easily translated into or discerned from quantitative values.[12,13] Likewise, qualitative sources, such as case studies, can be key complements to understanding structural, quantitative datasets or as a check to identify their divergence from theories or existing models anticipated results.[14,15]

Unstructured data are information in disparate formats and locations that make traditional data collection and use difficult. Such data include postings within virtual social networking domains or blogs, such as images, webpages, and published reports.

Data Providers

Data can often be accessed from two types of sources: data generators and data compilers. Data generators collect and process primary data to answer questions often where current resources do not exist. Data compilers gather, transform, store, and make accessible data that have already been generated.

Data Generators

When data are nonexistent or unsuitable for a study's objectives, researchers must generate new data. They may do so with direct measurements (including collection in the field or via satellites), surveys, or interviews. These new data are known as primary data, which researchers can then analyze or join with other elements to produce secondary data.

Researchers tend to collect and analyze data using numerical values (quantitative data) or in textual form (qualitative data). We found that data relevant to assessing conflict-instability-fragility and natural resources/environmental factors can range from highly quantitative national statistical data to qualitative event summary

[12] Jack Goldstone, Special Report: Using Quantitative and Qualitative Models to Forecast Instability (Washington, DC: United States Institute of Peace, 2008).

[13] Bruce Berg, Qualitative Research Methods for the Social Sciences, sixth edition (Boston, MA: Pearson, 2006).

[14] See Note 12, this chapter.

[15] Sambanis, N., Expanding Economic Models of Civil War Using Case Studies, Perspectives on Politics, June 2004, Vol. 2, No. 2, 259–279.

data. More specifically, researchers tend to generate primary or secondary data from four main activities:

- High-resolution satellites collecting Earth-imaging data with remote sensing techniques
- National governments and international organizations composing statistical data from required or voluntary submittals
- Academic research teams gathering remote data through field interviews and physical measurements
- Journalists reporting on conflict events and resource shortages.

Data Compilers

> **Example: SCAD**
>
> The University of North Texas and University of Texas at Austin developed the Social Conflict in Africa Database (SCAD) as a resource for analyzing social conflict events in Africa. The web-accessible database tracks social and political unrest events from 1990 to 2010 for 47 African countries. For each event, SCAD contains information on the location, timing, and magnitude; actors and targets involved; number of participants and deaths; government repression; and issues of contention.

Governments, businesses, nonprofit organizations, and researchers develop and compile data to help them set, analyze, and manage priorities, including data generated through their own actions or those acquired from other data producers. To improve access and minimize duplication of research efforts, databases are used to maintain, document, and share data and their sources. These data resources are often web accessible from various providers.

Databases vary in their size and purpose. Some contain only a single data type that the owner generates; others manage data related to a specific tool or analysis topic. Large databases and clearinghouses are used as collaborative platforms to manage data of interest to many agencies and organizations.

While not intended to be comprehensive, we identified several promising resources that focus on a broad range of conflict,[16] security, socioeconomic, population, natural resources, and environmental factors. These compilation sources act

[16] Previously discussed in Chapter 1, the definition for conflict drives what is considered a conflict or not. Conflict databases often differ based upon project specific criteria for what counts as conflict as well as limitations such as defining its duration, which has likely contributed to the development of the previously noted contradictory findings and limited the results utility for understanding and decision making.

as data banks of information from other producers. Examples of widely used and relevant data clearinghouses include the following:

- Correlates of War (COW) Project
- Peace Research Institute Oslo (PRIO), Centre for the Study of Civil War (CSCW)
- Uppsala University, Department of Peace and Conflict Research, Uppsala Conflict Data Program (UCDP)
- International Peace Research Institute, Oslo, Armed Conflict Location and Event Dataset (ACLED)
- National Counter Terrorism Center (NCTC), World Incident Tracking System (WITS)
- National Consortium for the Study of Terrorism and Responses to Terrorism, Global Terrorism Database (GTD)
- Climate Change and African Political Stability Program (CCAPS), University of Texas at Austin and University of North Texas, Social Conflict in Africa Database (SCAD)
- University of Illinois, Cline Center for Democracy, Social, Political, and Economic Event Database (SPEED)
- Stockholm International Peace Research Institute (SIPRI) and the International Relations and Security Network (ISN), Facts on International Relations and Security Trends (FIRST)
- Organisation for Economic Co-operation and Development (OECD), Environmental Data Compendium
- United Nation’s Statistical Division
- Oakridge National Laboratory LANDSCAN Population Datasets
- Columbia University, Center for International Earth Science Information Network (CIESIN), in collaboration with the NASA, Socioeconomic Data and Applications Center (SEDAC)
- US Office of Management and Budget (OMB), Geospatial One-Stop (GOS), Geodata.gov
- Environmental Systems Research Institute (ESRI), Geography Network.

We also identified US government agency and nonprofit organization efforts that develop and maintain many applicable natural resource and environmental data sets. Although the accessibility of these resources varies, many are either the international authority or are useful supplemental sources of national-level information:

- CIA's World Fact Book
- World Resources Institute's Earth Trends
- NOAA Climate Prediction Center
- US Geological Survey[17]
- USAID's FEWS-NET.

Other resources target specific natural resource sectors, such as the Food and Agriculture Organization of the United Nations, Water Systems Analysis Group at the University of New Hampshire, and the International Energy Administration.

CLASSIFICATION, INTEGRATION, AND MONITORING

Processing and Classification

Approaches and tools for assessing and predicting fragility require some form of data processing and classification. Regardless of the data type, these are key steps in data acquisition, analysis, projection, and model output synthesis.

Raw tabular data must be processed and categorized before they can be used for fragility analysis. Processing data ensures that disparate data sources can be combined into a complete and robust data set. In general, when processing data, analysts should consider the following characteristics:

- *Data gaps*. Any gaps in the data must be identified and resolved.
- *Common units*. All data sources must use the same units.
- *Common time-steps*. All data sources must be updated with the same frequency.
- *Common duration*. All data sources must extend over a common length of time.
- *Resolution*. All data sources must have a common resolution.

When processing tabular data, compromises in quality are likely needed to ensure data are compatible. Generally, the least-specific data source will drive the

[17] For example, the USGS provides both regional and country-specific mineral resource maps, which are available at: minerals.usgs.gov/minerals/pubs/country/maps/.

characteristics of the data set. For example, if one data source updates monthly and another updates annually, the compiled data set can only be updated annually. Thus, considering how the processing will affect potential uses is important. Some uses may require very reliable, precise data; others may have less stringent demands.

Similar to tabular data, remote sensing data must be processed before they can be used. The EM signals captured by the sensors often cannot be used directly to reveal information about the sensed scene. Other variables related to the sensed scene can be derived from intercepted EM signal. Obtaining this indirect infromation requires various levels of data processing. As part of its Earth Observing System (EOS) program, NASA defined five different levels of data processing (Table 4-1) to reflect the complexity and utility of the various stages of processing remote sensing derived data.

Table 4-1. Levels of Processing for Remote Sensing Data

Processing level	Definition
Level 0	Reconstructed, unprocessed data at full resolution; all communications artifacts have been removed
Level 1	Level 0 data that has been time-referenced and annotated with ancillary information, including radiometric and geometric calibration coefficients, and geolocation information
Level 2	Derived geophysical variables at the same resolution and location as the Level 1 data
Level 3	Variables mapped on uniform space-time grids, usually with some completeness and consistency
Level 4	Model output or results from analyses of lower level data

Source: NASA, "Data Processing Levels," outreach.eos.nasa.gov/EOSDIS_CD-03/docs/proc_levels.htm.

Sensors generate raw data and return them in a format generally unusable by analysts, often as raw bits. Many sensors have been paired with data algorithms and analysis software that automatically convert the raw data into a useable form. Once the data are converted, researchers and analysts can apply tabular or geospatial data post-processing, categorization, and integration techniques.

However, prior to integrating geospatial data, identifying and managing key metadata are necessary. All geospatial data utilize a specific coordinate system, such as latitude and longitude, and a geographic projection (a method used for translating a three-dimensional sphere onto a two-dimensional plane). To make geospatial data useable, one must identify these two key attributes so the GIS package being used can utilized the proper coordinate system and reproject the data into a common projection. The coordinate system and projections must match when combining or joining data, or these sources will not properly align, and the resulting analysis will be incorrect.

Data Integration

Once raw data have been processed into usable data sets (including a common coordinate system and projections), the next step is to integrate multiple data sets into a relevant analysis overlays or indexes, such as a fragility index. Indexes are compilations of related data sets that analysts can use for a common purpose.

Reviewing an index's planned and potential uses is important when compiling it. These uses will drive the index content, in terms of the data that need to be included and their properties, such as frequency and resolution. The primary uses of fragility indexes include the following:

- Early warning and early action information
- Evaluation of interventions
- Policy guidance
- Public awareness
- Research
- Risk analysis.[18]

> **Example: Serengeti**
>
> AFRICOM developed Serengeti system as an Africa-centric data repository and analytic interface. The system pulls from both external (open source) and internal non-traditional data streams. It is flexibly designed to accept data sets of any size or type. AFRICOM analysts can use Serengeti to analyze stability by generating maps, searching data resources and visualizing results, and generating automated reports.

Analysts are developing flexible data and analysis integration architectures to assemble quantitative and qualitative datasets as well as to aid in the ultimate multisource analysis. They can use these systems to compile, integrate, and analyze a range of topics and questions tied to assessing and addressing conflict, instability, fragility, and other complex concepts. This research flexibility requires large amounts of structured and unstructured data, capable backend architecture to manage the data, data management for both open source and secure sources, and user interfaces flexible enough to

> **Quantitative and Qualitative Data Triangulation**
>
> Using quantitative (data-driven) and qualitative (expert-based) knowledge in a complementary hybrid approach can increase the quality of analysis. This triangulation helps increase the accuracy of instability and fragility models by increasing confidence in data when the independent methods agree and can provide red flags or contextual information when the results disagree.

[18] See Note 7, this chapter.

select, integrate,[19] and display results. These so called "sandbox tools" require analysts to know the questions to ask as well as the use of data triangulation approaches.

Data Monitoring

Analysts can use indexes for monitoring purposes. They track how data sets trend over time and evaluate the impacts of events and planned interventions. Sophisticated monitoring tools, such as the MPICE tool, require rigorous definition of the problem to be monitored and the data sets used to monitor the situation. The identification of the dynamic being monitored sets the context.

> **Example: MPICE**
>
> The USACE-developed Measuring Progress in Conflict Environments (MPICE) tool measures progress during stabilization and reconstruction efforts. It allows users to set goals and develop indicators to track progress toward them. Indicators fall into two types: conflict drivers and institutional performance. The interaction between the two reveals progress toward stabilization. MPICE can be used by policymakers, analysts, planners, and program and project implementers.

ANALYSIS APPROACHES AND MODELS

While data, their availability, and integration are important inputs, their analysis and the later development of models require specific research questions, purposes, and contexts to produce useful and relevant output products. Conflict, instability, and fragility research already employs or could utilize a range of analysis and modeling techniques. How can these diverse data and information sources be utilized to generate knowledge about natural resources and environmental factors that helps analysts and decision makers understand, monitor, predict, and proactively reduce fragility, instability, and, ultimately, conflict? Alternatively, how can societies, states, and regions be made less vulnerable and more resilient?

Analysis approaches often help facilitate the framing and analysis of situation, problem set, and options. The following analysis approaches and models can be used to enhance the understanding of research questions and purposes:

- Explore key concepts and their understanding (conflict, fragility).
- Design new data collection (resolution, extent, time step).
- Explore the limits of precision, accuracy, and uncertainty.

[19] The GlobalNet capability may be making game-changing advances in this previously tedious process. Described as a "sensemaking engine" by Kalev Leetaru, GlobalNet's combination of supercomputing power and suite of analytical algorithms is already generating intriguing results from its massive network analysis, such as narrowing down the location of Osama Bin Laden to within 200 kilometers. See Leetaru, Kalev. "Culturomics 2.0: Forecasting large-scale human behavior using global news media tone in time and space" First Monday [Online], Volume 16 Number 9 (August 17, 2011).

- Examine flows of causality, interdependence, or degree of influence.
- Understand the limits to resilience and adaptation.

Addressing these analytical components is necessary to provide the needed practical inputs for Army, COCOM, DoD, and broader US government smart power missions and purposes. For example, predictive models can red flag a likely problem area, but not provide real-time early warning monitoring as a situation deteriorates to enable a rapid response. Likewise, ongoing monitoring can maintain this needed situational awareness but doesn't provide the detailed understanding to know how to best mitigate or even prevent such events ahead of time. Analysts need to know the purpose and intended end use to develop the appropriate modeling and tools. When applied together, such models and tools can provide true early warning and decision support functions to understand opportunities for reducing vulnerability and supporting the development of greater resiliency.

Statistical Analysis and Modeling

By far, the use of statistics on historical structural panel data is most commonly used analysis approaches for fragility assessment approaches and in conflict and instability predictive models. Using historical panel datasets (structured data) and standard statistical software packages (STATA, SPSS, etc.), analysts explore conflict and instability events through the use of parametric statistical analysis, where they perform after-the-fact testing of hypotheses (historical data) and the validity of theoretical models (explanatory and predictive). More recently, fragility research efforts and approaches use similar statistical methods to interpret, explain, and validate data for the purposes of monitoring fragility (present).

One often-used statistical approach is linear regression, which essentially looks for a linear relationship between independent and dependent variables. Regression analysis is one of the statistical techniques most used in conflict and instability studies. This technique uses historic variables related to the condition of a nation or region to forecast the future condition, trends, and profiles. For example, the Center for Army Analysis's (CAA's) Forecast and Analysis of Complex Threats (FACT) III uses regression analysis to extrapolate macro-structural trends into the future and predict whether countries are likely to be in conflict. Likewise, DARPA's Integrated Crisis Early Warning System (ICEWS) uses regression analysis to assess the degree of cooperation and hostility between governments and civil society actors using data factors, such as regime type and GDP per capita.

In the context of assessing fragility variables, AEPI had previously used linear regression and other statistical tests to explore and quantify the historical influence that environmental variables have on socio-economic variables descriptive of fragility.

The recent emergence of media capture and event databases offers novel opportunities to expand beyond historical panel data and their statistical analysis. Many of the event databases take unstructured media data and use trained human analysts to review news articles and fill out survey instruments recording key details. The resulting event data and lists can then be integrated with traditional panel datasets and indicators analyzed using the aforementioned statistical approaches. AEPI recently sponsored such activities in a parallel research effort to explore the relationships between conflict, natural resources, and their role in the continuation or resolution of conflict.

Qualitative Analysis and Fusion

As discussed previously, qualitative data can be generated in the form of surveys, interviews, review boards, content analysis, and case studies. While determining where qualitative data collection ends and analysis begins is sometimes difficult (such as in action research), the resulting analysis can provide keen insights into conflict, instability, and fragility situations, their proximate and indirect causes, and possible interrelationships with other dynamics, such as natural resources and environmental factors. Qualitative analysis can take many forms but is often referred to as the application of subject matter expertise.

Analysts also develop research questions and utilize the scientific method to explore the answers. Regional COCOMs, such as AFRICOM are embracing such approaches and use directed social science analysis to produce relevant outputs for decision makers, particularly using data triangulation. Effectively used, multisource data triangulation methods are a mainstay of academic researchers as well as traditional intelligence analysts. They are often used to increase confidence in analytical findings.

That said, qualitative case studies examining the complex relationships between conflict-instability-fragility and natural resource/environmental factors have provided greater visibility of these potential relationships, but often not the underlying causes, contributions, or social mechanisms, which would inform and support actionable mitigations.

Example: ICAF

The State Department and USAID developed the ICAF to enable a deeper understanding of conflict dynamics. The framework facilitates the process of pooling SME knowledge of a conflict via a workshop. SMEs review the groups in conflict, their motivations, drivers of the conflict, and opportunities to intervene. The framework results in a report that summarizes the consensus. ICAF is used by DoD, USAID, and the State Department.

Conflict- instability-fragility connections to natural resources and environmental change continue to challenge the understanding of researchers, military planners, and policymakers. These interactions require the exploration of new methods for data fusion and the development of a greater shared understanding of in-country, national, and regional dynamics.

Agent-Based Models

Given the inherent complexity of these connections, traditional statistical and expert-base research methods have not yet provided consistent findings or answers. However, agent-based models (ABMs), also known as multiagent models, can help provide new analysis options and tools for predictive and exploratory purposes. ABMs could be useful in examining the influences of natural resources and environmental change on conflict- instability-fragility, particularly where quantitative data are scarce and need to be integrated with further SME inputs on the human system side of the equation.

ABMs can be defined as representations of a target system in real life composed of a simulated environment and a collection of decision-making entities called agents.[20] As an autonomous entity, each agent uses internal cognitive and deliberative mechanisms to make purposive decisions to achieve goals.[21] Agents repeatedly interact, generating dynamics of the system as a function of its initial conditions, agent choices, and external shocks. ABMs can explore the dynamics of a target system that fall beyond the reach of purely analytical methods and can potentially account for heterogeneous, spatial interactions and reflect network effects. [22] Agents can represent individual, group, or organizational behavior and can be driven by conflicting incentives and result from learning, anticipation, and even strategic deliberation.

ABMs can be used as inference engines for complex systems to reduce the difficulty of reasoning about interactions among heterogeneous groups with dynamic memberships on multiple scales and in multiple contexts. This would allow analysts to enhance organizational capabilities to identify core problems and generate multiple scenarios of change. The primary purpose of considering more scenarios of change is not to only to achieve better predictive precision and accuracy, but also to enhance the robustness and resilience of policies derived from analyzing a wide range of plausible futures (better understanding the implications of real-world choices).[23]

When analysts cannot agree on a single family of models for studying the target system, ABMs could be used to generalize families of alternative competing theories within a single cohesive framework, which would enable them to identify the ontological boundaries and procedural inconsistencies of each component. This aggregating function of ABMs enables more systematic comparisons among

[20] Eric Bonabeau: Colloquium Paper: Adaptive Agents, Intelligence, and Emergent Human Organization: Capturing Complexity through Agent-Based Modeling: Agent-based modeling: Methods and techniques for simulating human systems PNAS 2002 99 (Supplement 3) 7280–7287.

[21] Ibid.

[22] Robert Axtell: Why Agents? On the Varied Motivations for Agent Computing in the Social Sciences, Center on Social and Economic Dynamics Working Paper 17, November 2000.

[23] Robert J. Lempert, Steven Popper, and Steven C. Bankes, Shaping the Next One Hundred Years: New Methods for Quantitative, Long-Term Policy Analysis, Rand Report 1626, 2003.

different alternative representations of the system, which are built on the non-overlapping assumptions of different theoretical approaches.

ABMs can also function as data fusion devices, where they can import data—that are partial and biased and may vary in credibility—into a common operating picture derived from the ontology of the model. ABM data fusion can combine qualitative narratives and individual case studies with quantitative data and create the backbone of intuitive, participatory communication and visualization tools for policy development, planning, and training.

However, it is important to note that ABMs outcomes are only as good as the available quantitative inputs and SME knowledge about the relevant actors. However, in the face of multiple uncertainties, Bayesian analysis can likewise offer another useful option for bounding and understanding such uncertainties.

Bayesian Analysis

Bayesian analysis is a statistical inference approach that uses some sort of observed evidence to calculate the probability of a hypothesis. A subset of statistical analysis, this approach is of special note because of its use in the development of the DARPA ICEWS model. Using the Bayesian technique, the ICEWS looked at the output forecasts (observed evidence) of several different agent-based, logistic regression, and geospatial models that forecast the occurrence of crisis-related events of interest (EoIs). Using Bayesian analysis, they then took these EoI values and essentially created new, hybrid EoI probabilities. Of note, it is likewise used in the context of climate change to link different models at various scales and to manage uncertainty probabilities.

MODELS AND TOOLS

Conflict, instability, and fragility research employ (or could utilize) a range of analysis and modeling techniques. These approaches and models are tailored for specific uses in the form of tools. Although they vary on the basis of intended purpose, most fit into one of three categories: predictive modeling (when something will happen), non-predictive modeling (exploratory and situational awareness), and scenario planning aids (planning, preparation and enabling action).

Predictive Models and Tools

Approaches, tools, and outputs vary in predictive modeling. The majority of approaches utilize national panel data to predict instability and conflict. Although the predictive models discussed in this report share the common goal of creating forecasts of conflict and instability, the methods and approaches vary in their temporal focus. Some forecasts are near term (Senturion), while others project out as far as 2025 (FACT III). The resolution of forecasts generally ranges from the subnational to international levels. Some of these approaches utilize geospatial capabilities to create interactive web-based or standalone visualizations of future conflict, while others generate individual-country-based assessments or reports. Outputs often include briefings or details on key individuals or political factions and their relationship to potential conflict.

Example: Senturion

Senturion is an agent-based predictive model, developed by the Sentia Group, which predicts the outcome of complex political events. The model uses SME interviews to gather data on critical stakeholders and then uses these data to simulate "agents," which follow a set of mathematical rules that synthesize political science, microeconomics, game theory, and spatial bargaining. Senturion is a proprietary software package used by the National Defense University, other defense agencies, and commercial clients.

Example: FACT III

The CAA developed FACT III to forecast internal conflict in countries around the world. The model uses 24 indicators to project fragility. For each country, the projected indicators are compared with historic data from other countries. Finally, the projected country assumes the conflict status of the two closest historic matches, for example, if Afghanistan (2020) is most similar to Bolivia (2000) and Sweden (1998), it will take the average conflict score of the two. The model, an ongoing research effort of the CAA, is run in a Microsoft Access environment.

Representing the majority of the current conflict and instability approaches, non-real time, predictive models synthesize past data or utilize deductive reasoning to accurately anticipate the future occurrence of an event so users can monitor the situation more closely. We identified several models and tools developed to forecast national or regional conflict and instability. Of these, most are oriented on predicting the likelihood that a country or region will experience instability or conflict in a near-term time horizon (usually 6–24 months). Often, these predictive models are driven by sets of political, economic, or social indicators derived from national statistical sources, such as polity, GDP, or infant mortality. Other instability and fragility models, such as the Fund for Peace, are distilled from a variety of qualitative sources—such as media and communication content, SMEs, and survey or polling data.

Predictive instability modeling also includes ABMs that generate simulations informed by specific sets of algorithms or rules to structure "agent" behavior and that can be used to generate hypothetical circumstances, explore scenarios, or provide predictions. ABMs have become an increasingly useful for instability and fragility modeling because of their ability to simulate the complex interactions between system and agents under certain conditions (such as political, social, or economic). Such simulations could be used to improve the reliability of such predictive models and tools. However, most of these predictive models and tools do not operate using real-time data inputs and are limited in their integration with more operational early warning systems.

Example: ICEWS

The DARPA ICEWS tool, developed by Lockheed Martin–Advanced Technologies Laboratories, is a predictive model that monitors, assesses, and forecasts crises to support decisions on how to allocate resources to manage them. ICEWS uses Bayesian statistics to synthesize three types of predictive models: logistic regression, geo-spatial networks, and agent-based models. The synthesized output is more accurate than that of the individual models. ICEWS uses many types of data, including macro-structural country data (such as GDP per capita), SME interviews, and event data (6.7 million news stories from 75+ sources). ICEWS is under development, with a goal of supporting military commanders with near-real-time forecasts and predictions.

At time of this report, the only known, unclassified example of a predictive tool that offers both monitoring and a limited predictive capability in near real time is ICEWS.[24] Using a media information capture model, ICEWS searches news articles for action words that individually represent key actors, major cities, and event types. These lists are all compiled by human subject area experts and must be manually updated. In addition, ICEWS incorporates some predictive capabilities in the form of a virtual workspace, where a range of models can be applied to make forecasts about a country's future unrest and test the impact of different indicators on those predicted outcomes for the limited purpose of expert hypothesis testing. The predictive model component requires more complex knowledge and understanding of the underlying models to effectively utilize the capabilities.

Exploratory and Situational Awareness Tools

Non-predictive tools differ from predictive models in that their purpose is not to accurately forecast future events (does not suffer from the "my model is better than yours" weakness). Rather, non-predictive tools are geared toward aiding in the compilation of multiple source data, performing analysis, and, in some cases, interactively exploring relationships. Their primary purpose is to better understanding complex interactions and dynamics. While they purposes are different from predictive cousins, they can use similar data inputs and employ many of the same analyses modes as in predictive models. Such tools can also create user specified outputs, including maps, vulnerability assessments, and reports.

[24] Sean O'Brien, 2010. "Crisis Early Warning and Decision Support: Contemporary Approaches and Thoughts on Future Research," International Studies Review, volume 12, issue 1, pp. 87–104.

These categories of tools focus their models and outputs on answering a particular question or monitoring progress so users gain insights into a past or current situation. They are mostly purpose-built models or suites that are topic specific, such as RebelLand, developed by GMU, and MPICE, developed by USACE, and the Alert Lists, developed by USAID. These approaches, models, or tools utilize integral analysis methods that are often peer reviewed and focus on a specific relationship or set of goals. Their more rigid frameworks allow researchers or decision makers to have more trust in the accuracy of the tool's outputs but, as a result, are less flexible. Often, they are used for research or to inform governmental decision-making processes.

USAID Alert Lists

The USAID alert lists are an example of a fragility index. The alert lists rank states in terms of overall instability and fragility to better inform USAID mission priority and resource allocation. The lists scores state fragility across "four domains of government activity (economic, political, security, and social)." Thirty-three indicators are used currently to develop these scores though further development of this analysis tool is focusing on adding indicators to better reflect environment dynamics.

Real-time media monitoring and situational awareness capabilities, such as the European Commission's Joint Research Center Europe Media Monitor (EMM),[25] are coming on line to help analysts sift through the high volume of daily news material and gain better situational awareness within their areas of responsibility. For instance, EMM retrieves thousands of online news reports daily, clusters them into stories, and attempts to extract basic information from those articles, such as the city, number killed/injured, and key names. While EMM doesn't yet have more sophisticated analysis features (still a human analyst function), the expansion of these types of exploratory capabilities offer untapped resources to distill and understand in real time.

Likewise, ABM approaches are emerging that can generate simulations, informed by specific sets of algorithms or rules, to structure "agent" behavior and that can be used to explore hypothetical circumstances and scenarios. These applications are becoming increasingly useful for instability and fragility modeling because of their ability to simulate the complex interactions between system and agents under certain conditions, such as political, social, economic, and environmental. Such simulations could be used to explore relationships and, ultimately, improve the reliability of fragility early warning.

Scenario Planning Approaches and Tools

Scenarios and war gaming are traditional tools long used by military planners. For example, US Army TRADOC, Army War College, and USAF Air University annually develop scenarios and support war game exercises and, in recent years, have even included non-traditional elements, such as energy and natural

[25] European Commission, Joint Research Center, EMM News explorer, About EMM NewsExplorer Web Page, emm.newsexplorer.eu/NewsExplorer/readme.html.

resources. Traditional inputs that inform scenario planning design and processes are often qualitative (SMEs, surveys or polling, or content analysis) and quantitative (country or region demographics and conflict-related statistics) data used to add detail to the topical narratives. In recent years, mock news reports and simulations have been introduced to enhance participants' exploration of the envisioned "what if" scenarios. Exercise outputs often include after-action recommendations, user-generated reports, or briefings to guide short- or long-term strategies and capability plans.

National Defense University, among others, has also explored more sophisticated inductive- and deductive-driven, modeling-based scenario planning tools.[26] These social and computational models and tools are options for helping explore the interplay between trends, uncertainties, and employed alternatives in a dynamic and connected international system.

Air Force Research Laboratory (AFRL) has likewise been advancing such capabilities with their development of the National Operational Environment Model (NOEM). Using an open source, web-based tools, this suite of capabilities is integrates ABM model of a population, systems dynamics models to baseline and project conditions (including sensitivity analysis), and game theory based "what if" type dynamic scenario capabilities.

Example: NOEM

NOEM is a strategic analysis and assessment tool that provides researchers, analysts, and decision makers with an open source, web-based platform to gain insight into complex interactions between a populace and their environment (security, economic, and social), such as SSTR. While still evolving, the NOEM suite of capabilities includes an ABM for representing a population, systems dynamics model for producing a current and future baseline conditions, and a simulation tool for exploring the complex relationship and outcomes from decisions.

Such capabilities hold great promise for use in exploring different courses of action and working through the non-traditional implications and opportunities stemming from fragile or unstable nations or regions as well as the downstream implications of our kinetic decisions. Users of scenario planning tools, such as decision makers or military planners, can potentially use such approaches to assess the implications of a range of conflict events or fragile states and use a multiple-path analytical process to work through proactive conflict resolutions or how, when, or if the government should intervene in a fragile nation or region, particularly with acute natural resource challenges and tensions. Moreover, these opportunities for "out-of-the-box" thinking can help identify possible "black swan" threats so that future security environment contingencies are not limited to past and current mindsets.

[26] Frank, Aaron., Pre-Conflict Management Tools: Winning The Peace, Center for Technology and National Security Policy, National Defense University, February 2005.

EARLY WARNING SYSTEMS AND DECISION MAKING

The aforementioned analysis approaches, models, and tools can potentially provide insights into fragility, its early identification, and proactive action. However, many of these available tools are not yet widely used in an operational sense or in US government decision-making processes. Operational tools already in use seem to take the form of either frameworks or early warning systems and have the express purpose of, and have evolved for, decision maker use.

Frameworks can often help facilitate the framing and analysis of a situation, a problem set, and options. They set out standard constructs, such as USAID's Instability and Fragility Alert lists, and processes, such as ICAF, that analysts and decision makers can use to structure an analysis, but they do not provide integral analysis capabilities. Such frameworks can serve as the foundation of a decision-making process, to which quantitative and qualitative analysis and dynamic simulation tools can be added, such as NOEM.

Whereas ICAF leverages a process to elicit and synthesize diverse qualitative data, the US government and European Commission continue to develop remote sensing-based, quantitative "system of systems" networks. These long-term systems are intended to capture, analyze, and disseminate information to diverse end users, from scientists to policymakers. For example, the Global Earth Observation System of Systems (GEOSS) has been under development by the US government and scientific community. It is intended to offer users a single gateway for near-real-time environmental data and information, to enable users to better integrate diverse data sets, and to facilitate access to complementary models and decision-support tools.[27] The European counterpart to GEOSS is the Infrastructure for Spatial Information in the European Community (INSPIRE), which has a similar goal of creating a geoportal for access to diverse spatial datasets and services. In parallel, the European Union (EU) is also developing the Global Monitoring for Environment and Security (GMES) system. Although the goals and vision behind GMES are similar to those of GEOSS and INSPIRE, GMES is envisioned to be directly oriented toward serve the needs of policymakers.[28]

[27] US EPA, "Global Earth Observation System of Systems (GEOSS) and the Group on Earth Observations," Accessed 28 June 2011 at http://www.epa.gov/geoss/.

[28] GMES, "Overview," Accessed June 28, 2011 at http://www.gmes.info/pages-principales/overview/.

Building on existing system of systems architectures, such as GEOSS, purpose built, early warning systems are already being developed to provide forewarning of specific environmental threats to a country or region. They can provide high-level predictions and detailed analysis, as needed. Early warning systems often rank and communicate threat levels in simple terms, such as high, medium, or low. These purpose-specific operational early warning tools, such as FEWS-NET, are already providing forewarning several months in advance.

Other strategic approaches, such as CCAPS, are being developed to not only integrate remote sensed data but also predictive models, which are then used to assess vulnerability of countries, regions, or localities to the impacts of climate change (see Chapter 6). However, these have not yet made the transitions from research approaches to true strategic early warning systems with end user focused mechanisms.

Example: FEWS-NET

The FEWS-NET is a USAID data synthesis and analysis tool used to identify threats to food security across the globe. The tool monitors food security issues by tracking geospatial and tabular data in the following categories: agro-climatic monitoring, markets and trade, livelihoods, and remote monitoring. FEWS-NET uses these data to assess overall food security risk by identifying both the potential hazard and vulnerability of households. The FEWS-NET website (fews.net) includes all outputs, including short- and mid-term food security projections, detailed analyses, and alerts.

Example: CCAPS

The Climate Change and African Political Stability Program (CCAPS) at the University of Texas at Austin seeks to understand how climate change and vulnerability to natural hazards intersect with demographic, social, and political sources of weakness. With a focus on the African continent, the CCAPS uses geospatial analysis to map data on four aspects of vulnerability: climate related hazard exposure, household and community resilience, governance and political violence, and population density. This results in vulnerability maps that illustrate where insecurities exist for each aspect and as a composite.

Resource Summary

During the course of this study, we identified geospatial data resources (Appendix E) and several relevant government analysis and early warning systems (Table 4-2 and Appendix G).

In general, many of the identified capabilities are not set up to answer the mission relevant “so what?” questions, meaning they do not help analysts understand what their outputs mean. This may be part of the reason that many are not incorporated into existing mission-oriented, decision-making processes. The exceptions are frameworks and early warning systems, which are designed and purpose built to provide information to decision makers.

Conflict, instability, and fragility approaches, indexes, and tools generally do not consider natural resources or environmental factors. However, understanding the linkages between fragility, human sectors, and natural resources is important in effectively studying, monitoring, and acting on emerging trends and threats in these non-traditional areas. This is a critical gap in current US government capabilities, particularly if we intend to minimize costly responses and become more proactive in the application of our national elements of power.

Table 4-2. Identified Approaches, Models, Tools, and Systems for Analyzing, Monitoring, and Predicting Aspects of Conflict, Instability, or Fragility

Model name	Creator	Temporal Coverage	Coverage	Environmental indicators?	Classification of analysis	Software support	Outputs
SCAD	University of Texas at Austin	1990–2010	Africa, country-based, local	No	Non-predictive, open source database for historical analysis	None	Searchable conflict database
SPEED	Cline Center for Democracy, University of Illinois	1970s–Present	Country, subnational, local	Yes	Non-predictive, human coded event database based on human coded media reports	None	Event data, geospatial layers, and analysis reports
GlobalNet	NCSA, University of Illinois	Near, mid, and long-term forecast	Global, regional, national, sub-national	No, potential for future inclusion	Massive data-capture, content and networks analysis	Supercomputer, with multiple programs	Tone signatures used overtime to monitor and create near-long term projection.
ICAF	Department of State	Present	Country-based	Yes	Non-predictive, qualitative, question-based, consensus process	None	Reports, determination of potential entry points for government engagement
Serengeti	AFRICOM	Present	Africa, regional, local	Yes, limited to physical environment	Geospatial, all-source, and socio-cultural non-traditional data integration system	Multiple, with Savanna user interface	GIS maps, automated reports
MPICE	USACE	Past, Present	Country-level, local	Yes	Scenario planning, content analysis, quantitative, expert knowledge, and survey and polling	In-process	Theater-level metric system for progress tracking and implementation
FACT III	CAA	Forecasts 2011–25	Global, country-based	Yes, limited to physical environment	Predictive, statistical projection with K-nearest neighbor classification algorithm	None	Predictions, maps
USAID Alert Lists	USAID	Present	Country-based	No, potential for future inclusion	Quantitative, indicator-based statistical analysis and index integration approach	None	Fragility and Instability Alert Lists report
Senturion	Sentia Group	Near-term forecast	Country-based and subnational	No	Predictive, qualitative, agent-based analysis	Senturion simulator	Conflict outcome predictions and analysis
FEWS-NET	USAID	Present	Regional/country-based	Yes	Monitoring/near-term predictive, geospatial (web-based and stand alone) and livelihood question-based survey	Early warning explorer, decision support interface, geospatial water requirement satisfaction index, geospatial stream flow model	Interactive maps, vulnerability assessments, update and alert products, and briefings
NOEM	AFRL	Present, Near-term forecast	Country-based, subnational, and local	No, potential for future inclusion	Predictive and exploratory, agent-based, system dynamics, and game theory analysis	NOEM application suite (Java-based)	Exportable graphs and charts
ICEWS	DARPA	Near, mid, and long-term forecast	Global, country-based	No	Predictive, logistic regression, geospatial, Bayesian analysis, and agent based modeling	Geographic information system (GIS) mapping software	Projections, maps, reports
CCAPS	University of Texas at Austin	Present	Africa, country-based, and local	Yes	Predictive, question-based, geospatial analysis	GIS mapping software	GIS maps

Chapter 5
Proposed Framework and Architecture

From our findings, we determined that the US interagency does not have an existing or emerging system that addresses and integrates conflict, instability, fragility (or conversely resiliency), human activity sectors, and natural resources/ environmental factors, particularly tools capable of utilizing geospatial resources. Conceptually, these areas of study have often been stovepiped with divergent lexicons and working definitions. Government analysis and early warning capabilities have also been narrow in their intended scope. Chapter 4 summarizes general resources and capabilities, but we recognize the need to develop and propose both a conceptual framework and a functional architecture that can integrate the data, analysis, and knowledge products necessary to meet the mission and data needs described in Chapter 3 and provide insights into effective actions.

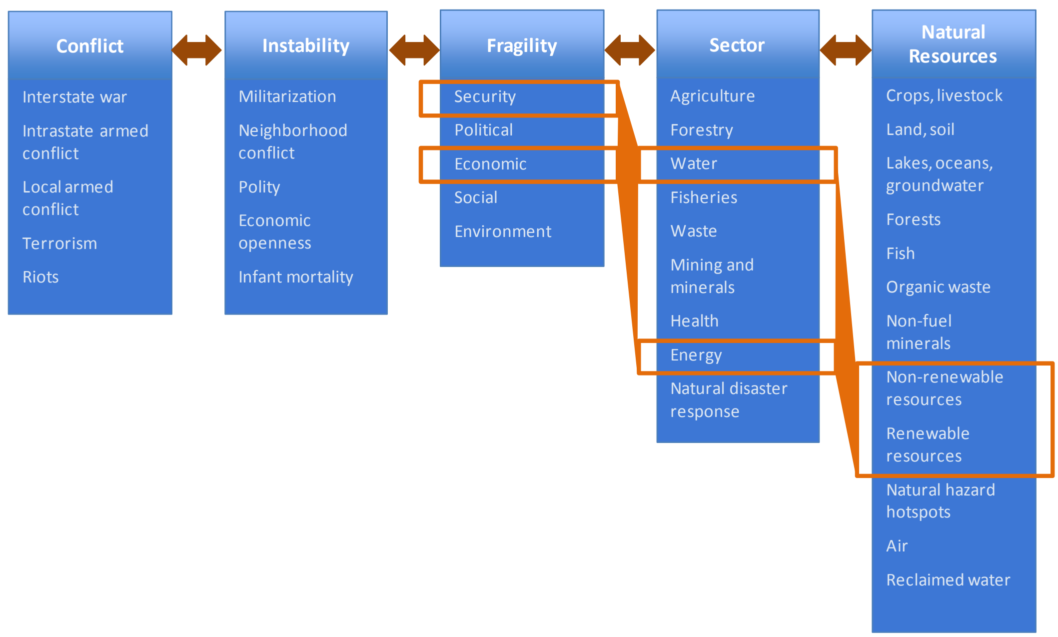
We propose a common conceptual framework that leverages Army and other agencies (USAID, for example) fragility approaches to help align mission-relevant concepts, such as conflict and instability, to the functional and technical focus areas, such as human activity sectors and natural resources/environmental factors. Using this conceptual framework, we have adapted and propose a US interagency, functional architecture for analysis, planning, early warning, and enablement to help the Army, regional COCOM, DoD, and government national security analysts better understand the dynamics between mission implications of conflict, instability, and fragility (including governance and livelihoods), human activity sectors, and natural resource/environmental factor domains as well as inform decisions on how to proceed forward.

Proposed Fragility Framework

Conflict, instability, fragility, and natural resource/environmental factor analysis is currently constrained by the lack of integrative concepts and accessibility challenges that hinder the exploration of country and location-specific dynamics. As discussed in Chapter 1, conflict, national security, natural resource, vulnerability, resilience, and climate communities of practice have some conceptual and lexicon mismatches that can bedevil clear terms of reference, research questions, findings, and, ultimately, decision making. This suggests that conceptual dialogs on mapping conflict (armed or social tension), instability, fragility, human activity sectors, and natural resources/environmental factors are necessary to understand, analyze, and monitor underlying relationships for the purposes of supporting actionable decisions. Likewise, the difficulty of intra- and inter-disciplinary data access continues to hinder bridging these diverse communities of practice.

We build on the working conceptual definitions provided in Chapter 1 to develop and propose an interagency, conceptual framework to help researchers, analysts, and planners frame inquiries and structure the relevant quantitative and qualitative information available from existing external sources. Although many conflict and instability models follow a linear approach, this conceptual framework acknowledges the bidirectional nature of these interactions and their inherent complexity. The conceptual framework (Figure 5-1) is used to organize inquiry, data, analysis, and output/products for the proposed functional architecture.

Figure 5-1. Proposed Conflict, Instability, Fragility, Sector, and Natural Resource Framework



We assembled this fragility-based framework to facilitate a balance between core concepts, objects of referent, and national security relevance. These missions increasingly emphasize support of non-traditional intervention and engagement roles for the military. Fragility—comprising security, political, social, and economic dimensions—can be seen as a "Rosetta stone" between the 3Ds communities and is useful to study the policy-relevant linkages with natural resources challenges. Spurred by early discussions with USAID CMM and technical advisors, this conceptual mapping was explored during the January 2011 USAID "Conflict, Fragility, and the Environment" workshop, which examined relationships between fragility and environmental indicators.[1]

Once linked to a functional architecture and interagency capabilities, this framework will help analysts explore relationships between variables that may be germane to planning for, or reacting to, situations in fragile states. In addition, this

[1] USAID, *Conflict, Fragility, and the Environment: A USAID/DCHA/CMM Experts' Workshop: Summary Report*, May 2011.

mapping of fragility to the impacted natural resources can help further establish military relevance, informing capability and contingency planning, and military engagement efforts. As this proposed framework is still evolving, additional research and analysis is needed to fully assess natural resource and environmental factor relationships with human sectors and the respective fragility components, particularly using temporal and geospatial explicit data.

FUNCTIONAL ARCHITECTURE

We sought to advance the understanding of relevant data acquisition, spatial integration technologies, analysis modes, output approaches, and other collaborative architectures that represent an expanding the Army, DoD, and US interagency toolbox for fragility analysis, early warning, and enabling capabilities. Given that conflict, instability, and fragility indexes are often not a sufficient basis for making policy decisions or even actionable plans, we sought to utilize the proposed interagency conceptual framework, identified data streams, and existing government capabilities to layout a hybrid,[2] fragility-based functional architecture that could realize the advantages of Goldstone's "multiple method" early warning approach.[3] As discussed in the 2010 AEPI study, hybrid architectures can increase confidence in analysis and early warning results, particularly when the independent data and methods agree through data triangulation, provide corroborated signpost warnings, and generate red flags when the results disagree. A conceptually grounded, hybrid architecture could greatly increase the accuracy, explainability, and utility of a conflict, instability, and fragility early warning system that incorporates natural resources/environmental factors.

Proposed Architecture Components

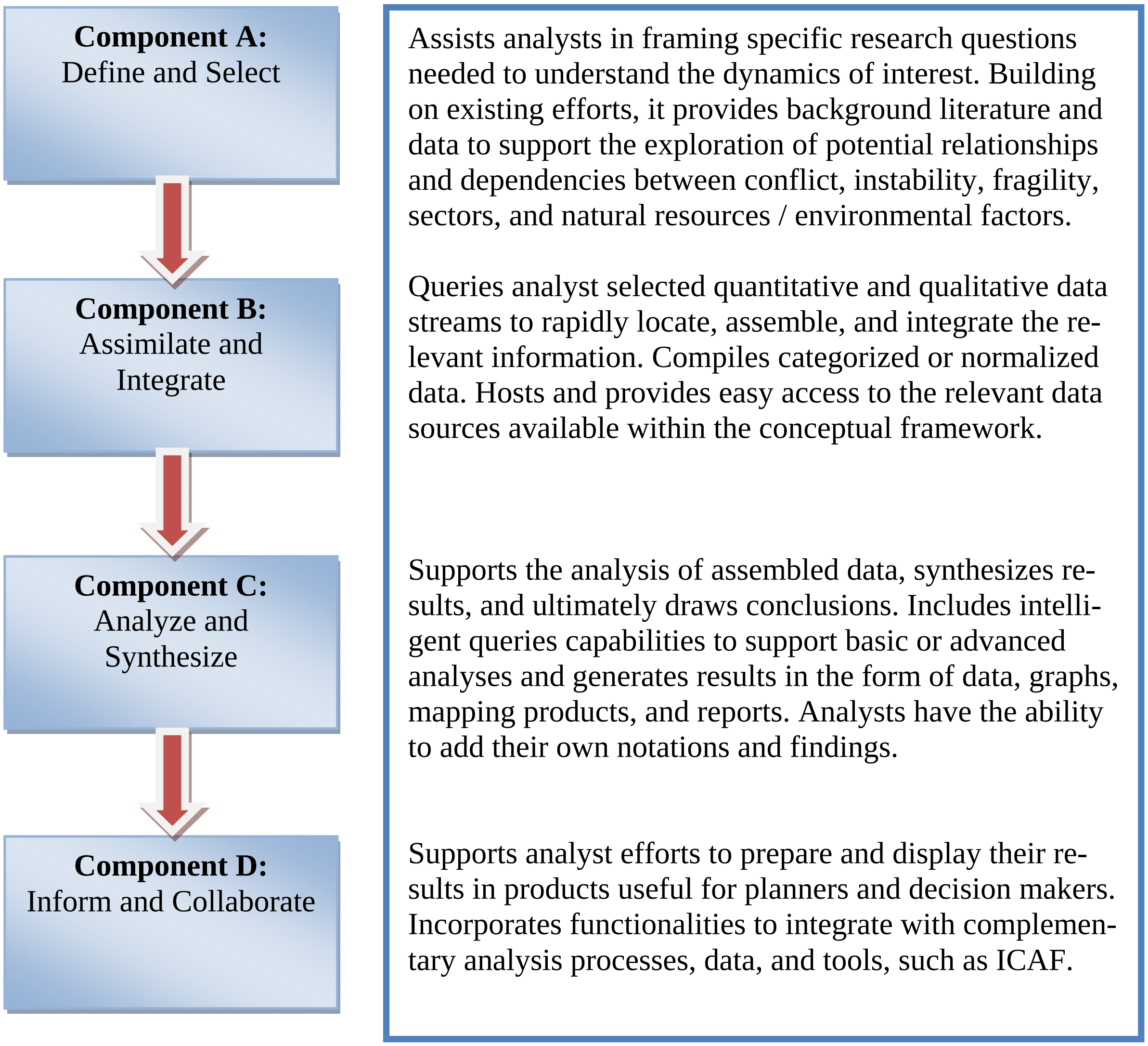
Building on the identified needs and capabilities of Chapter 3, the proposed interagency functional architecture will integrate existing government resources and capabilities to support more effective analysis, planning, signpost monitoring, and collaboration for whole-of-government missions, such as bilateral engagement (including mil-to-mil engagement), HADR, and SSTR. Focusing on Army, DoD, and US interagency user needs, we divided the proposed functional architecture into four component process steps to allow analysts and planners to use each component individually, in tandem with other components, or throughout the analysis life cycle. Figure 5-2 illustrates the four components and presents them in a linear analysis process, though such analysis may often be iterative in practice.

---

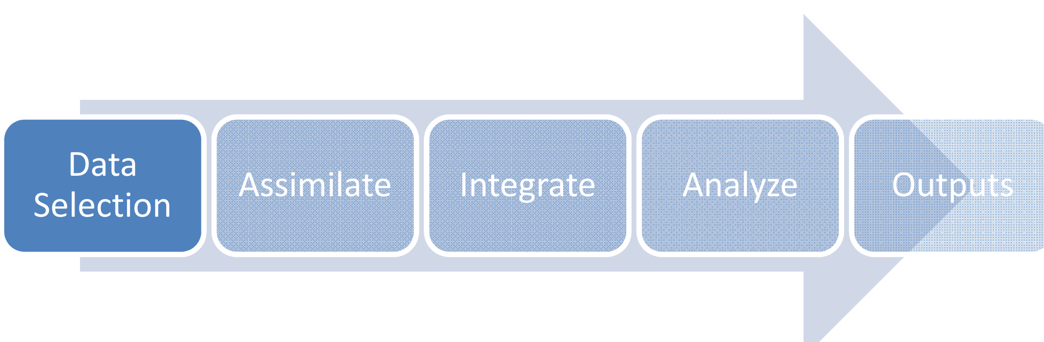
[2] We use the term *hybrid* to reinforce the need to systematically leverage both quantitative (data-driven) forecast models and qualitative (expert-based) "structural analogs" in a value-added manner. See Note 10, Chapter 3, and Note 16, Chapter 1.

[3] Jack Goldstone, *Special Report: Using Quantitative and Qualitative Models to Forecast Instability* (Washington, DC: United States Institute of Peace, 2008).

Figure 5-2. Proposed Functional Architecture Components



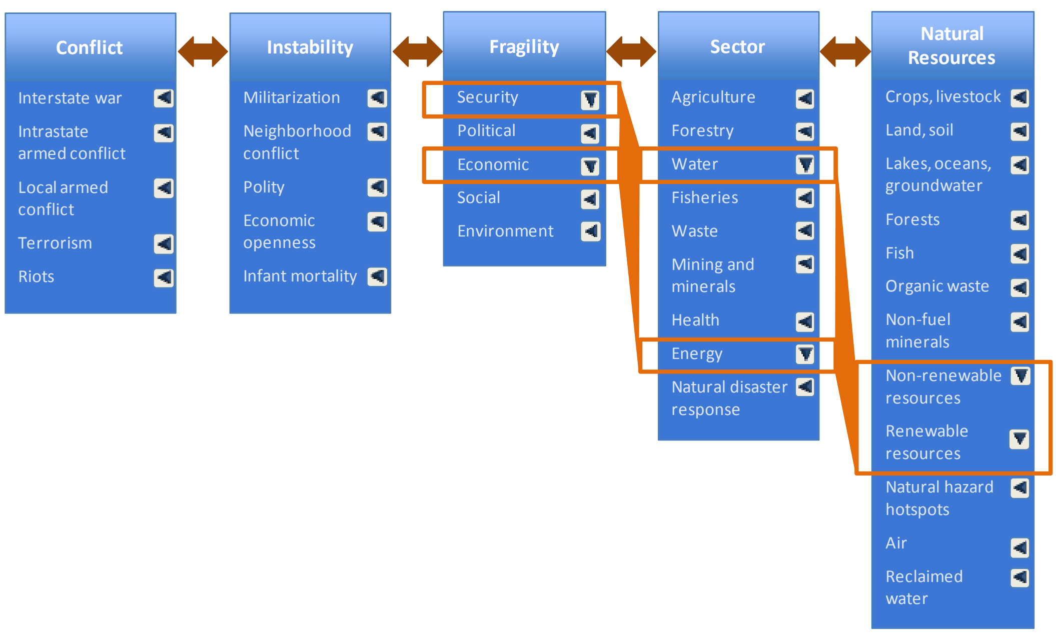
Component A: Define Approach and Select Data (Knowledge Center)



The functional architecture is first intended to help the user understand the conceptual framework and identified relationships between conflict, instability, fragility, human activity sectors, and natural resources/environmental factors. The knowledge center component will inform users of the available data streams and analysis interfaces, helping them construct their inquiry and approach to efficiently and effectively address the research question. The knowledge center will use a fragility-based conceptual framework and provide the user with a visual aid for mapping out potential relationships linking conflict, instability, fragility, sectors, and natural resources/environmental factors.

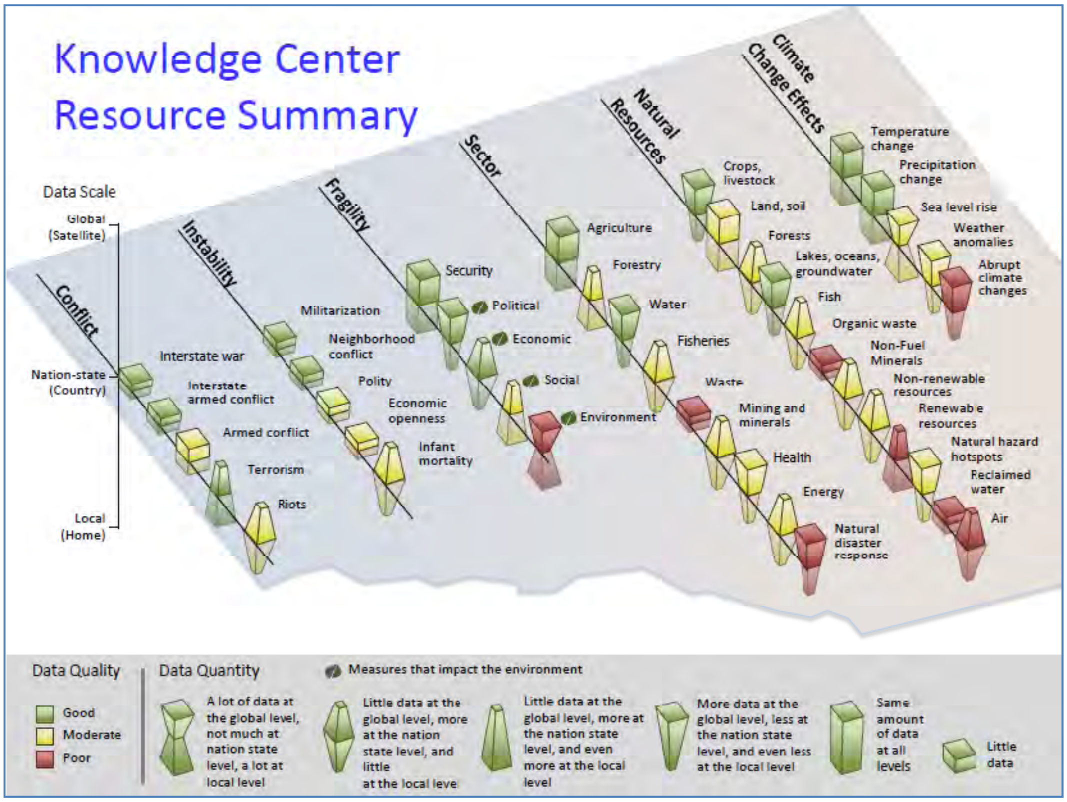
The knowledge center data summary approach tool will integrate different interfaces with various types of quantitative and qualitative data to provide the user with background on preexisting relationships to help formulate the research question. For instance, this could be achieved using interactive drop-down options and a concept mapping approach that would yield a selection of the most recent and salient research, data sets, etc. (Figure 5-3).

Figure 5-3. Potential Concept Relationship Mapping Inquiry

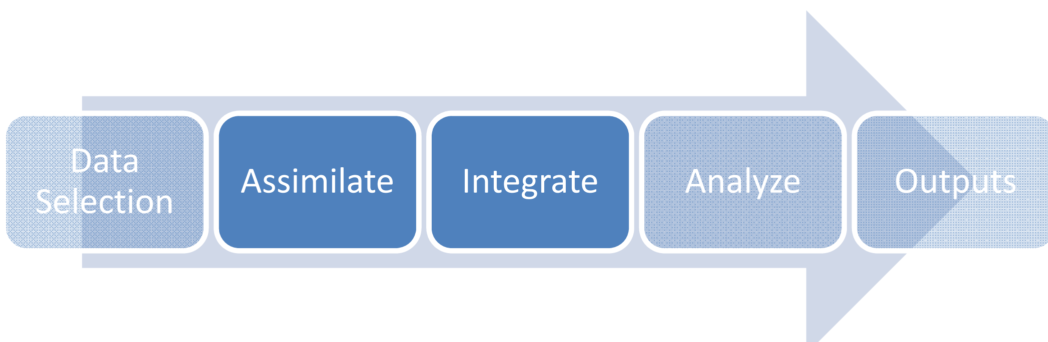


This component will be capable of visually summarizing the various data types in the functional architecture. Data summaries will include representations of quantity and quality information. Detailed drill-down tags would present metadata, such as data formats, sources, and limitations (temporal and spatial coverage), maximizing the efficiency of the research approach development. The knowledge center should also include guidance to troubleshoot potential issues users may encounter when using the fragility framework and analysis tools. An analyst may not necessarily have a predetermined question before using the fragility framework and analysis tools. The knowledge center can assist the user in framing an inquiry approach and offer examples of research questions and how they can be applied to the fragility framework and analysis tool. The knowledge center will further assist the user in targeting appropriate data and resources (Figure 5-4) to address the research question by including links to supplemental data resources.

Figure 5-4. Knowledge Center Data Quality and Resource Availability Summary



Component B: Assimilate and Integrate



This component will ensure analysts are able to obtain and integrate the relevant data and information from a repository filled with geospatial layers (including remote sensing imagery), national statistics, subnational studies, event data, or media reports. However, understanding how to gather, update, process, and integrate these data is an important component of the functional architecture.

Process Overview

We propose utilizing a service-oriented architecture (SOA) approach to data and information for the functional architecture. The SOA approach will account for data and information available from external sources that do not need to persist in the functional architecture as well as data that will need to be stored. Maintaining accurate and up-to-date information requires a systematic approach. At a high level, such a process includes six steps:

1. Identify reliable information sources and data sets.
2. Acquire primary and secondary data through manual collection, automated data harvesters, or data sources.
3. Vet the information to record metadata and identify data limitations.
4. Manipulate the data to align with data standards and formatting protocols.
5. Store data in the main repository.
6. Manage the data through regular updates and user feedback.

As data collection and transmission methods are diverse, gathering each type requires unique approaches. We discuss these approaches in the next subsection, with a focus on publicly available data.

Addressing Specific Data Types

The data repository will include statistical data in tabular form, geospatial vector files and raster data sets, remote sensing images, event or media reports, and research studies or publications (Chapter 4). The use of manual or automated collection methods, scale or resolution of the data, frequency of collection and updating, and access issues will influence how the data are gathered.

Data Assimilation

Data can be captured in a variety of ways, using conventional data entry methods or state-of-the-art data assimilation tools. Manual methods are mostly used as a component of configuring automated tools for data extraction and manipulation.

Data harvesting/extracting tools allow data capture from websites by manually training the tool agent to automatically search for desired content. Scripts created can be automated to run at scheduled intervals or on demand, resulting in automatic data collection and file creation in various formats with the ability to publish and integrate collected data.

Open-source tools offer methods to analyze, profile, transfer, and cleanse internally and externally collected data. These tools aid in data integration and manipulation and administering and monitoring data quality, and they take the place of traditional extract, transform, and load tools. Grid computing architecture and middleware coordinate network resources to provide necessary connections and processing capability.

With reliable and secure open-source data being made publically available, interagency data virtualization techniques (often known as cloud computing) could be set up to facilitate access, aggregate, and transform data across multiple disparate source systems provide fast and accurate use of readily available data from resources where data have already been gathered and validated.

One advantage of data virtualization is the ability to access trusted, real-time open-source data without the expense of having to store and maintain replicated copies. Another advantage is the use of data management tools to integrate virtual data with other internal and external data sources to provide dashboards, forecasting, and other useful reporting content. As open-source data continues to grow, automated data virtualization techniques will be essential in handling data volume, streamlining the information-gathering process, and minimizing associated costs.

Unstructured content could be integrated using semantic web technologies. The structure of language easily lends itself to interpretation on the basis of the ability to decipher paragraphs, sentences, nouns, verbs, synonyms, antonyms, and other grammatical content. Electronic dictionaries and thesauri are resources for creating processes to allow morphological or linguistic analysis of unstructured text. As a result, vocabulary-rule-based extraction methods such as tokenizers, sentence splitters, gazetteer lists, analyzers, taggers, chunkers, and other semantic-based processing resources provide the ability to extract and reference unstructured data.

A taxonomy or hierarchical list of related terms can be formally defined within ontologies. These can further relate unrelated concepts and terminology in addition to incorporating taxonomies, resulting in identification of pertinent content within unstructured text when incorporated within grammar-based semantic web processing tools.

TABULAR STATISTICAL DATA

National statistical data sets are common and made readily available by governments, organization, businesses, etc. The data typically come in tabulated data sets that use Microsoft Excel or.CSV formats. Because a lengthy time is required to collect and process data for an entire country, most of these data are generated from annual country reports. Resources are available that aggregate these data; data collection should focus on credible and reliable resources. Gathering these data requires manual collection, as well as preprocessing the data before entering them into the data repository. Because not all data are at the nation-state level, the data should reference the region, country, and subnational scales when available.

Geospatial Vector and Raster Data

Gathering geospatial data varies in ease and complexity because a wide variety of sources are available. For country-level statistics, base layer, vector data are easily attainable. However, usable spatial data require metadata for conversion to the same datum and projection. Data assimilation will require some pre-processing. Using raster data sets may also present a challenge because converting grid values from one projection to another can be difficult without diligent efforts to obtain and maintain such metadata. From our research, we found that geospatial data are mostly cross-sectional, so updates to geospatial files are not as common as those for other data types.

Remote Sensing Images

Satellite images of the Earth's surface and atmosphere can be a reliable source of information to recognize changes over time. This type of data is available from government agencies and through proprietary software. NASA, for example, has an extensive range of platforms for remote sensing. Constellations of satellites such as the Afternoon Train, or "A-Train," capture imagery and data to improve understanding of the Earth's systems, including climate and weather. Many of the satellite images are publicly available through NASA's main website.

The NGA is the US government's dominant provider of geospatial intelligence, including imagery, imagery intelligence, and geospatial information, to support national security objectives. Declassified remote sensing images are available through a variety of distributors, such as Raster Roam and NGA-Earth. Through the Measurements of Earth Data for Environmental Analysis Program, the CIA has declassified a significant amount of imagery taken since the launching of the earliest intelligence satellites.

Access to the various sources of government-generated remote sensing imagery varies depending on who requests it, but tapping into these resources is a consideration in strengthening fragility analysis. Frequent collection of Earth-images can generate a large amount of data. Automatic data feeds are useful for updating this data type. Challenges with these data include large data files, variances of spatial coverage, and variances in available data years. However, these data are available at the subnational scale and, as a result, offer significant opportunities.

Media and Event Data

The functional architecture should include inherent or ported capabilities that allow users to access relevant event or news reports for their particular interests. Leveraging existing repositories is preferred as independent capabilities require an extensive time to mine, transform, translate, and geocode the data, particularly if utilizing human-coded anthology. Obtaining the information requires the use of software applications to comb through open-source material (in particular, global news wires) using keyword searches. Once the software collects the data, they must be processed for relevance and georeferenced to the location of occurrence.

Event data are mostly qualitative, but quantitative data may be available within the reports or result from frequency of reporting. Because events occur at irregular intervals, these data should be updated at set intervals, such as monthly following the initial acquisition of historical data. As it appears, gathering this information is time intensive, but event data are particularly useful, often providing detail down to subnational or even local scales.

Several existing projects rely upon capturing media reports or event data to analyze conflict drivers and monitor stability. For example, the USACE and Cline Center's PPNRA project has been leveraging SPEED, which uses a human-coding ontology to mine and geocode subnational event data from BBC summaries of world broadcasts from the 1970s to the present. In doing so, these event data support analysis efforts to better understand the relationship between natural resource activities and their relationship to civil unrest and conflict. Another example is the University of Illinois, National Center for Supercomputing Applications (NCSA) GlobalNet Project. This computational approach captures global news reports and models the documents' information as part of a larger "knowledge network." The network is then cross-sectioned to develop a stability measure for a given actor, such as a country, and can then be analyzed to provide up-to-date information on the interactions and sentiments within and between societies, which could be used to anticipate future activity and patterns.

Web 2.0 Capture

Web 2.0 describes applications that support and facilitate sharing of participatory information, such as Twitter and Facebook. The Web 2.0 site content is generated through the participation, interaction, and collaboration of site users. Examples of Web 2.0 applications include social networking sites, blogs, video-sharing, and wikis. Web 2.0 applications are non-traditional but can be an inherently valuable source of current information related to societal interaction and sentiment.

For assessing and predicting fragility, instability, and conflict, Web 2.0 technolies and applications could be especially valuable data source as the relationship between a nation's government and population is a critical factor that is often not easily discernable through more traditional statistical approaches. For example, most instability and fragility indexes were not sensitive to the social discontent building prior to the civil unrest across North Africa and the Middle East during the "Arab Spring" of 2011. However, through sentiment analysis or opinion mining (such as those offered by GlobalNet), using contextual analytics to determine attitude or tonality of a speaker or writer with respect to a particular issue or event, Web 2.0 data mining and analysis applications become direct sources for discerning individual or societal opinions and emotions. For instance, posts to personal Twitter accounts by citizens in a nation can be valuable for understanding subnational sentiment and provide clues or foreshadow conflict, instability, or fragility. Like traditional media summaries and derived event data, methods for capturing Web 2.0 content are diverse, including human-coding or using software algorithms to arrive at content-specific information.

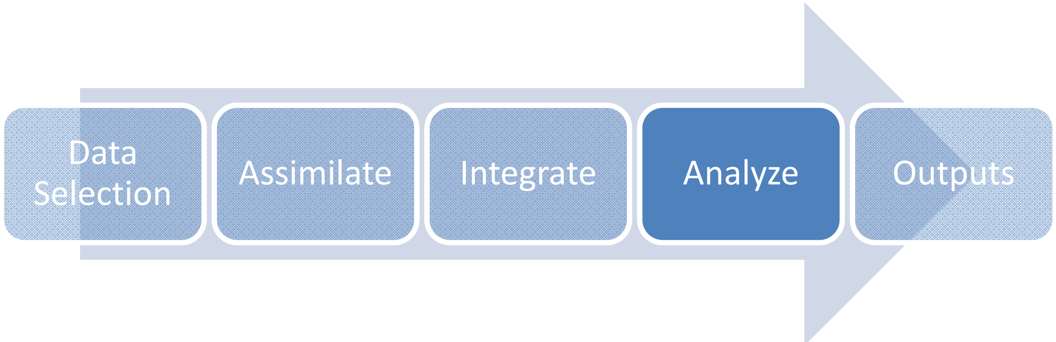
However, social media are not a panacea as they can present greater complications for analysis than traditional media sources because the data providers are more decentralized and unknown. Users may also use subcultural dialects or codes to avoid scrutiny by local security forces, making useful insights difficult to obtain. The decentralized nature of social media also presents the "opportunity" for intentional data contamination via state-sponsored misinformation campaigns. Although social media are a rich and growing source of information, they also present new data and analysis challenges to effective use.

Research Studies and Publications

National, subnational, and local data and insights are also available from studies or reports published by research institutes and nonprofit organizations. Such studies are sometimes only available on the organization websites and do not reach the major data libraries or clearinghouses. This data type can provide useful field data that supplements nation-state scale data. Examples include interviews from or surveys of local villages. The AFRICOM Serengeti tool, for example, focuses on "non-traditional" sociocultural data from sources such as unpublished gray literature from non-governmental organizations to generate a variety of data-rich products to inform decision makers. The disaggregation of source material requires manual search methods, review, and uploading. Data-gathering efforts can be streamlined by acting on recommendations from users and the identification of the main research groups for each country, region, or topic.

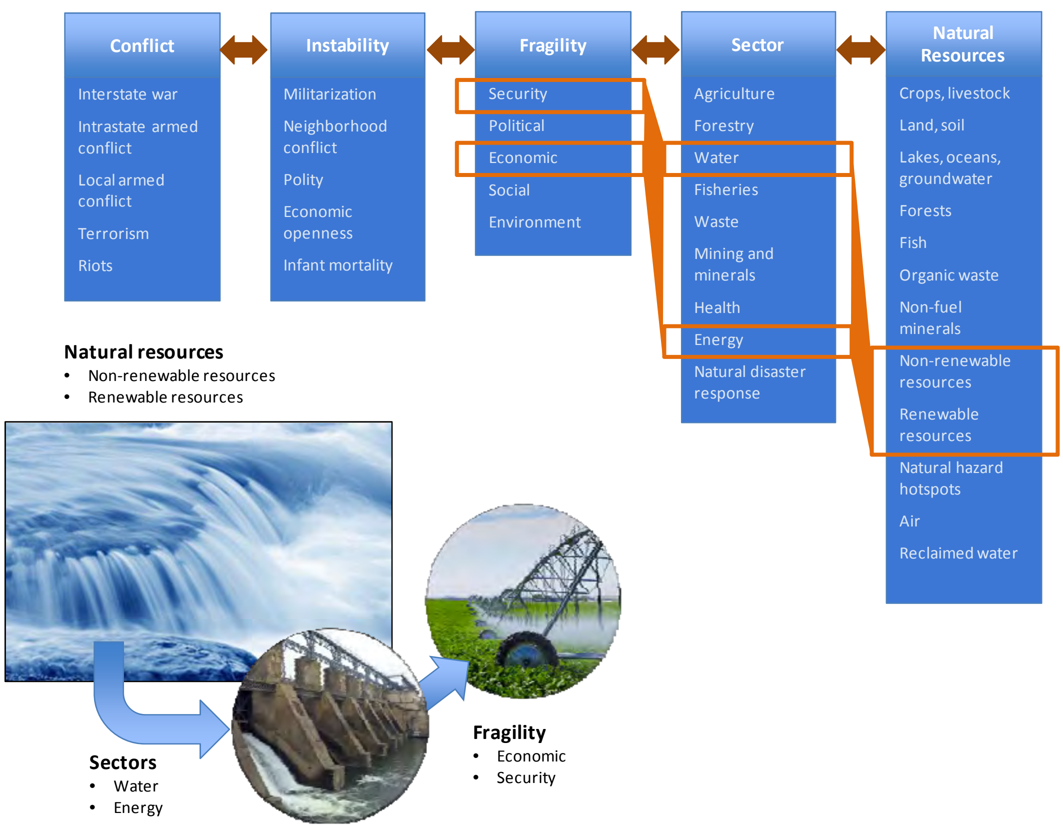
Unstructured data—which can consist of report text, audio, images, e-mails, blog posts, Tweets, etc.—are any data that do not have a well-defined model for information access. Unstructured data have significant value in obtaining information related to analyzing conflict, instability, and fragility dynamics. Although unstructured data have largely been untapped, information technologies and applications have increasing capabilities for leveraging its use. The potential for mining and analyzing unstructured data to capture pertinent information is significant. Successful text, audio, and image mining to better analyze and predict fragility will depend on available resources and capabilities resident within various US government agencies.

Component C: Analyze and Synthesize



This component of the functional architecture will support the analysis and synthesis of the compiled data and ultimately draw conclusions. These functionalities will support a suite of known analysis process and tools. This functional component will provide an analysis process framework that helps the analyst structure the analysis in an efficient and repeatable manner (Figure 5-5). Its primary function is to support the generation of grounded, transparent, and triangulated findings that can be directed to tailor product types for use in the "Inform and Collaborate" component.

Figure 5-5. Example of Architecture Analysis Approach



ANALYSIS APPROACH

From the data compiled, this functional architecture component provides guidance and options using the conceptual framework to guide analysts through the process of using the tool to answer their core research question and outputs. It helps analysts in four ways:

- *Understand underlying relationships and dynamics*. Analysts need to identify the relationships and understand the underlying dynamics of a particular area of concern. Understanding the causes of a situation is necessary for effective planning for contingency or engagement operations.
- *Incorporate and retain institutional knowledge*. The tool cannot capture all information about a given situation: the analyst also needs to consider his or her own expertise and institutional knowledge. The framework provides formalized methods to supplement the tool's analysis and conclusions with external knowledge. This will lead to more robust and documented conclusions.
- *Identify challenges and gaps*. The framework helps analysts understand potential problems with their conclusions. Understanding and explaining these problems is necessary for robust conclusions. The framework also helps analysts identify gaps in their analysis. Analysts can then develop strategies to correct these gaps.
- *Develop actionable findings for decision-making and action*. The framework helps analysts reach a conclusion that answers the given question. It helps them identify data that support their conclusion and explain it to decision-makers in a relevant and useful manner.

The functional architecture inherently supports analytical data triangulation efforts. It specifically enables the assembly of data-driven analysis of quantitative nation state data sets and supports the use of complementary qualitative knowledge. This is significant because the analysis can be made to be more robust and authoritative but also produce better products that aligned with various agencies respective analyst cultures and missions.

STATISTICAL ANALYSIS

This feature enables analysts to explore the data through the use of one of many different statistical packages that the subcomponent can recommend to the user. It shows how the conflict, instability, and fragility factors and natural resource/environmental factor metrics have changed over time in a country. Analysts can overlay multiple time-series data sets simultaneously. The subcomponent allows overlaying of these time-series data sets with event data. This helps the analyst understand what various factors looked like before, during, and after an event.

Statistical packages are software suites geared toward performing statistical analysis. Statistical packages can enable analysts to quickly and efficiently process relevant data through standard statistical procedures, often performing several different functions or tests at once. Statistically analyzing the quantitative and qualitative data outputs from the analysis tool helps the analyst draw and solidify conclusions. Current statistical packages vary greatly in ease of use, access, and complexity. Simple packages with general capabilities, such as Dataplot and SOFA Statistics, are free and available in the public domain, whereas other more complex, specialized packages with additional capabilities may include a usage fee and additional equipment. This also applies to geospatial statistical add-ons, such as ESRI ArcGIS Spatial Analyst.

Leveraging the historical panel data, this subcomponent package leverages user friendly statistical modules to enable analysts to set up and understand the statistical significance of select data sets. It should include the capability to conduct sensitivity analyses for the purposes of understand underlying drivers with relationships. This subcomponent should also include uncertainty analysis capabilities that help identify confidence levels.

For instance, the integrated statistical analysis capabilities can help analysts understand how a country of interest compares to countries in its cohort. Analysts can identify similar countries on the basis of a specific factor or combination of factors. Analysts can then draw upon their subject matter expertise with those countries to generate grounded and informed findings.

Geospatial Statistic Analysis

Geospatial analysis approaches are increasingly used in the analysis of conflict and natural resource management, but fragility is a new application. Leveraging established ArcGIS Spatial Analyst and other spatial packages, this subcomponent should help enable new analysis options using tabular and geospatial data in powerful and novel ways. The subcomponent enables analysts to overlay multiple data sets and run complex spatial statistics, helping them identify relationships at the regional and subnational scales. Most quantitative data can be analyzed using this subcomponent, from native vector files and raster images, to tabular nation-state data, and increasingly geocoded event data.

Geospatial Heuristics Analysis

While geospatial statistics may offer new analysis opportunities, ArcGIS and other spatial packages can also be used to aid with qualitative heuristics approaches. This experience-based approach uses deductive reasoning to identify a question, frame the problem set, and find a good solution. It is the application of subject matter knowledge, which is often used in a geospatial analysis context. In short, these are qualitative methods that seem to work in specific context and should help enable new analysis options using tabular and geospatial data in powerful and novel ways. As with geospatial statistics, this subcomponent enables analysts to overlay multiple data sets and help them work through planning and policy decisions. However, while they may work and are sometimes faster, they are not mathematically backed analysis mechanisms and should be acknowledged as such.

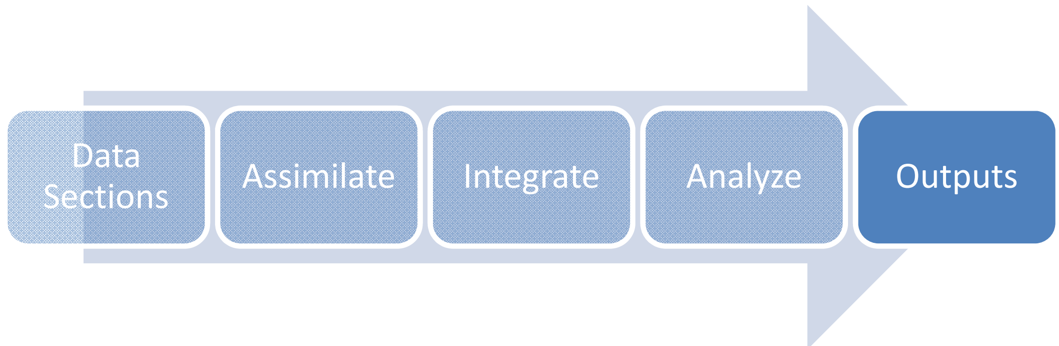
QUALITATIVE DATA DISTILLER AND VIEWER

This subcomponent allows analysts to review qualitative data sets—such as media summaries, reports, or interview results—that cannot be easily analyzed with quantitative techniques. This subcomponent allows users to read and annotate relevant qualitative data.

> **Content Analysis Example: FfP**
>
> The Fund for Peace (FfP) develops an annual ranking of 177 countries called the Failed States Index, using a content analysis tool, the Conflict Assessment System Tool. Data are compiled from thousands of articles and reports using content analysis algorithms. After expert review and analysis, these processed findings are compiled into an index that ranks countries by stability across 12 social, political, and economic indicators.

Content analysis is a research approach that examines the words, phrases, and concepts in written media. Generally, it focuses on the frequency of certain terms or relationships between concepts and uses these relationships to uncover patterns and meanings. Text is often coded (often human coding but increasingly using software algorithms), and content analysis software can then be used to perform the analysis. The aforementioned PPNRA and NCSA GlobalNet projects both rely on this research approach to facilitate enhanced understanding of conflict events and societal interaction. For example, GlobalNet utilizes global news data from open-source intelligence outlets, such as the Foreign Broadcast Information Service and BBC Summary of World Broadcasts. These non-traditional content analysis approaches can be used to more quickly distill the relevant qualitative inputs and give analysts and decision makers an agile and useful fragility analysis and early warning architecture.

Component D: Inform and Collaborate



This component helps the analyst prepare and display results in useful end products—actionable for analysts, planners, and decision makers—and collaboration capabilities for making these outputs meaningful.

Open-Source or Classified Products

Many data sources of potential use in assessing fragility have accessibility challenges. Data accessibility for users within and across US government organizations continues to be a challenge but is also opportunity in designing an analysis tool that can bridge many diverse communities of practice. Classified or FOUO efforts have and will continue to serve traditional national security functions, such as NIEs, threat assessments, and planning. However, "open-source" applications efforts are being recognized for their utility supporting coordination, bilateral engagement (including mil-to-mil engagement) because access is less restricted and can be shared with non-US government partners. The development of transparent fragility approaches that utilize open-source data and architectures could be expanded to include current and future threats related to environmental sectors and natural resources. Such capabilities can help augment the former while facilitating the latter. Direct engagement with the Army, DoD, and other government efforts in these areas could support opportunities for collaboration and enhance the utility of open architecture approaches, so we recommend a bifurcated architecture.

Dashboard

This subcomponent includes a dashboard that displays a summary of the analysis and provides broad situational awareness at a glance over a range of quantitative and qualitative output (Figure 5-6). Dashboards modules are often metric driven and designed to quickly render a comprehensive view of analyzed data. They can be used for navigating to the modules or components of an application. This subcomponent, which leverages the conceptual framework, could be designed and optimized to handle the conflict, instability, fragility, human activity sector, and natural resource/environmental data sets.

Figure 5-6. Example of Interactive Dashboard in DARPA ICEWS

A dashboard should include multiple subcomponents, each optimized for displaying analyzed data in different ways, and should be developed in collaboration with the analysis and planning communities. This collaboration will make it relevant and helpful for analysts to gain a deeper understanding of the underlying internal and international relationships. Current conflict and fragility tools have dashboards very similar to this diverse, subcomponent approach. Serengeti, developed by AFRICOM, has its own user interface, Savanna, which leverages non-traditional data in Serengeti. Because it is built with several subcomponents, users are able to generate maps and model human terrain, build automated reports, and search data resources and visualize results. Savanna can also create summary outputs and products at three different levels of detail: "Quick Look," "Topic Reports," and "Deep Dive."

Collaborative User Interfaces

Effective sharing and visualization of data outputs and results from the analysis tool requires an effective user interface. The list of available software platforms is exhaustive, but an overwhelming majority includes some form of integrative geospatial data management capabilities that use mapping software to create visually accessible outputs and products. GIS software desktop products have become a common tool used in the natural resource management and environmental science communities and can similarly strengthen the analysis of how such factors can impact fragility. Many available geospatial tools allow for integration of different raster and vector data types. The current market leader in this category is ESRI ArcGIS Software, which offers extensive data analysis capabilities, database management, extensive support of data formats, and a robust user knowledge base with software support and training. Another grouping of geospatial tools focuses more on raster-based image analysis, including

ERDAS IMAGINE 9.1, which is designed to extract data from raster images. A more commonly recognized example of an image analysis platform is Google Earth, which is easy to navigate and offers a basic service that is free to use.

Selection of the appropriate geospatial analysis platform depends on the current and future needs of the user community. Issues that make some platforms more appropriate than others include cost, necessary upgrades or updates, training requirements, ease of installation, maintenance, available workforce and training, and vendor support.[4]

Report Products

Much in the same way that this framework accepts a variety of research questions, the end product must span a number of reports, with a dynamic structure to fulfill the diverse needs of the mission community users and decision makers. This subcomponent of the functional architecture assists analysts in generating and producing briefs, fact sheets, and reports that vary in structure, detail, and emphasis. It should focus on streamlined report development and effective presentation of the key information.

> **Analysis Outputs Example: Savanna**
>
> Serengeti, an Africa-centric data repository, uses an analyst interface called Savanna, which is flexible in tailoring output products to meet user needs. AFRICOM analysts can generate maps, model human terrain, search and visualize data resources, and build automated reports.

Summary of Framework Analysis

An overview of the conceptual framework used is key for laying out the terms of reference and paradigm. This enables a planner or decision maker to quickly understand the motivations and analytical aperture used in the development of the research question, type of data considered, and type and level of analysis. This knowledge ensures better communication and transparency, which ultimately increases decision-maker comprehension and confidence in conclusions. The target audience can ask more specific questions about the data, visuals, and findings, which might provide insight into the mission application and utility provided.

> **Analysis Outputs Example: FEWS-NET Famine Alerts**
>
> The FEWS-NET offers outputs appropriate to meet a range of user needs. For example, famine alerts identify critical food security situations in African nations, which can be useful for quick, effective action by policy and decision makers.

[4] United Nations Statistics Division, Software Options for Operational GIS in Professional Environments, Workshop on International Standards, Contemporary Technologies and Regional Cooperation, February 4, 2008.

Bottom Line Up Front and Main Message

Depending on the target audience and purpose, this subcomponent could be communicated with formats such as the ubiquitous quad chart, executive summary, briefing, or complete discussion of findings. Regardless of the application, the standard bottom line up front or key findings should be aided by the architecture but requires human professional judgment. For example, an interactive or standalone map may best answer a question of fragility related to relationships between two or more countries. Addressing the vulnerabilities of a specific country would likely be best presented as a map or country summary fact sheet. Regardless of the way in which this section is presented, this part of the end product is reserved for the results of "Information Synthesis."

Visualizing Results

Knowledge-dense visuals are as much an art form as a science. That said, this subcomponent will be greatly aided with the graphical interfaces described above. Whether traditional analysis maps, dynamic mind mapping, or interactive visualizations, this subcomponent should aid in their development and collaborative deployment and tailor these products to the analyst or decision-maker needs. Regardless of the end use, they should reflect the conceptual framework and amplify the main conclusions or the key takeaway messages. Where not restricted or classified, these products should be made available to other users of the system to support the virtual community of practice.

EARLY WARNING SIGNPOSTS AND FRAGILITY ASSESSMENT

> **Analysis Outputs Example: CCAPS**
>
> The CCAPS produces output maps that visualize areas of elevated vulnerability to climate change and other risks within Africa. Vulnerability visualizations are important to the analyst and decision maker for both identifying current areas displaying indicators of fragility as well as for informing future planning and policy needs.

The conceptual framework and functional architecture were developed to support the analysis and communication of the relationships between conflict, instability, fragility, human activity sectors, and natural resources/environmental factors. However, it should also monitor and generate mission relevant warning flags when acute and chronic issues are detected. Analyst inquiry and analysis will help develop a clearer understanding of the relationships between the fragility, human activity sectors, and natural resources/environmental factors, which will aid in identifying specific at-risk dynamics within a regional COCOM's AOR. This actionable information will aid planners, teams, and decision makers in proactively and collaboratively acting on future trends that may impact country fragility and national security interests.

Likewise, the functional architecture should provide the current suite of conflict, instability risk, fragility (including vulnerability), and sector resilience monitoring capabilities in a smart power conceptual frame. Automated capabilities should assemble known and updated data streams to identify signpost and trends of concern. In addition, early warning products should include subnational-scale analysis and dynamic products that enable easy drill-down analysis on demand. Instability and fragility alert lists may be a familiar product included, but they must be capable of providing more actionable information. Although this early warning component may not be open access, it should be easily accessible as widely as possible within the government community of practice. The end product will highlight or discuss the human activity sectors or natural resources that are most fragile, why, and opportunities for effective, proactive smart power engagement.

COLLABORATION, ENABLEMENT, AND ACTION

The final subcomponent is integrated virtual collaboration capabilities. These should be accessible and useful regardless of mission location and conditions. For example, the limited telecommunication capabilities after the Haiti 2010 earthquake or broadband in Angola. As such, analysts and practitioners require a suite of collaborative platforms that should enable effective interaction via easy-to-use interfaces and function across multiple technology platforms. The purpose of such a platform is to expand the communities of practice and users of the functional architecture and to easily share best practices by enabling access to the unclassified data, analysis, and products. Such interactions should enable the rapid deployment of crisis-related virtual coordination centers that enable broader combined force, partner nation, and non-governmental organization engagement.

Furthermore, these subcomponents should be linked back to functional resources and government partner agencies. For example, a HADR commander sees the importance of forestry in a disaster zone and should have collaboration resources to connect with the appropriate USDA Forest Service international office for SME support. Although collaboration approaches are not this study’s focus, its importance for HADR, SSTR, and engagement missions is central to the utility of this functional architecture and its ultimate relevance. Three potential collaboration systems identified through the course of this study follow.

Emergency Response Asset Picture

DoD is developing the Emergency Response Asset Picture (ERAP) tool to address the need of personnel involved in crisis response at the strategic and operational levels. It is an expansive management tool that better coordinates federal, state, tribal, and local responses during a crisis. ERAP’s purpose is to consolidate dispersed information from various sources into one central system. It is designed to aggregate data from many different sources and of many different types to render visual reports to improve situational awareness and capabilities for crisis response. Federal, regional, state, and local government and relief databases can link in with the ERAP tool through aggregation and normalization of data sources and can ultimately produce aggregated data and reports that identify supplies and services most needed during HADR operation.

All Partner Access Network

The All Partners Access Network (APAN) is a platform for collaboration and information exchange between DoD and external countries, organizations, agencies, or individuals that do not have access to DoD's traditional systems and networks. APAN capabilities assist with professional communication and networking, establish channels of communication and information flow, improve situational awareness, and facilitate crisis response, disaster relief, and training and exercises. APAN was used during the HADR operations in Haiti following the January 2010 earthquake. It strengthened the international HADR effort's capacity to coordinate relief activities, such as restoring the major airfield to receive relief supplies, organizing and controlling relief flights in and out of Haiti, broadening the support base, and establishing additional distribution routes for needed supplies.

Active Worlds Platform

Used by the Army G-2, this is a non-traditional approach to integrated virtual collaboration through a virtual reality pavilion. Active Worlds Platform has been cited as an emergent and cost-effective capability that allows users to deliver interactive, real-time content over the web. This international platform has become a popular tool for educators: institutions, teachers, and students use it to explore new concepts, visualize theories, implement more creativity into curriculum design, and expand social learning. The Active Worlds Platform is free and works with a 56K modem, which improves accessibility where broadband access is limited or disrupted. In addition to the technology, the real-world utility of such a platform can be accelerated by seeding the virtual pavilions with enabling resources, particularly when tailored to the concepts and priority areas of interest. For instance, if fragility is indeed considered the inverse of resilience, posted international or government analysis, playbooks, and toolkits could be identified,[5] adapted, or developed to inform and enable practical action. These types of resources would be part of and support the mil-to-mil engagement as well as broader interagency bilateral exchange activities.

---

[5] The World Bank has developed toolkits for use in its and other development programs with an eye toward fostering greater resiliency. For example, it developed the Building Resilient Communities: Risk Management and Response to Natural Disasters through Social Funds and Community-Driven Development Operations," which was specifically developed to identify disaster risk management issues, design, and implement appropriate responses. See at: siteresources.worldbank.org/INTSF/Resources/Building_Resilient_Communities_Complete.pdf.

Chapter 6
Climate and Security Nexus

This study has explicitly focused on the intersection of conflict, instability, fragility, and natural resource/environmental factor analysis, monitoring, and early warning systems. Recent policy and practitioner interest require a better understanding of the connections between fragility and climate change. In particular, the policy and intelligence communities are increasingly concerned that climate change impacts on water, agriculture, and energy could make nations with limited resilience and adaptive capacity even more fragile.[1,2] Within the context of their fragility and natural resources/environmental factor efforts, both the Army and USAID have sought to identify mission-relevant climate vulnerability assessment and adaptation approaches.

In this study, we have sought to crosswalk concepts, identify opportunities to develop US military mission and functionality relevant connections, and better understand how fragility could be used as an integrative operating concept to address environmental and climate change related threat multipliers.

Climate Change and National Security

Over the past three decades, climate scientists have greatly advanced and improved their understanding of how climate change will impact the natural and human environments. During this time, global climate models have become more robust and specific at predicting a range of changes in climate parameters. However, although the international and US climate change research communities have made progress, politics—and the wide gulf in operating language and applicability—have hindered efforts to functionally applying climate science to national security concerns. Warfighters and climate scientists are worlds apart in their missions, world views, and language.

Despite this divergence, the US national security community recently began to debate and study how climate change may affect national security interests. In April 2007, the Center for Naval Analyses released a military advisory board report, *National Security and the Threat of Climate Change*, which set the stage for this discussion. In early 2008, the Fiscal Year 2008 National Defense Authorization Act, Public Law 110-181, Section 951, gave the defense community statutory guidance to start considering climate change impacts. Section 951 specifically

[1] Dennis Blair, "Annual Threat Assessment of the US Intelligence Community for the Senate Select Committee on Intelligence," Director of National Intelligence, February 2, 2010, intelligence.senate.gov/090212/blair.pdf.

[2] National Intelligence Council (NIC), *Global Trends 2025: A Transformed World*, 2008, www.dni.gov/nic/PDF_2025/2025_Global_Trends_Final_Report.pdf.

"required that the next national security strategy and national defense strategy include guidance for military planners on the risks of climate change, and that the next quadrennial defense review examine capabilities the armed forces will need to respond to climate change."[3]

Later in 2008, the NIC warned that although "climate change is unlikely to trigger interstate war … it could lead to increasingly heated interstate recriminations and possibly to low-level armed conflicts. With water becoming scarcer in several regions, cooperation over changing water resources is likely to be increasingly difficult within and between states, straining regional relations."[4] In 2010, Admiral Dennis Blair, Director of National Intelligence, asserted that climate change's intensification of water resources, natural disaster, and arctic change challenges over the next 20 years will "aggravate existing world problems" and tax US military resources.[5]

The 2010 QDR asserts, "The rising demand for resources, rapid urbanization of littoral regions, the effects of climate change, the emergence of new strains of disease, and profound cultural and demographic tensions in several regions are just some of the trends whose complex interplay may spark or exacerbate future conflicts." As the 2010 QDR was being released, the US Joint Forces Command (USJFCOM) released its Joint Operating Environment (or JOE), which identified climate change as one of its 10 key trends that will impact US military forces, focusing on potential natural hazards, coastal inundation, and new natural resources exploitation tensions.[6]

The Department of State and USAID are reinforcing their commitment to better handling cross-cutting energy, environmental, and climate challenges. In 2009, USAID CMM prepared a discussion paper, *Climate Change, Adaptation, and Conflict: A Preliminary Review of the Issues*, which started a dialog and learning process throughout the development community. The late-2010 release of the QDDR signaled a shift in policy to establish parity between diplomacy and development missions and to sharpen the focus on the importance of transnational issues, such as energy, environment, and climate.[7] The QDDR states, "The impact of climate change will likely constrain our own economic well-being and may result in conflicts over resources, migrant and refugee flows, drought and famine, and catastrophic natural disasters," which well aligns with DoD's initial assessment.[8]

[3] Rymm J. Parsons, *Taking Up the Security Challenge of Climate Change* (US Army, Strategic Studies Institute, August 2009), www.strategicstudiesinstitute.army.mil/pubs/display.cfm?PubID=932.

[4] See Note 2, this chapter.

[5] See Note 1, this chapter.

[6] USJFCOM. *Joint Operating Environment (JOE)*, 2010, www.jfcom.mil/newslink/storyarchive/2010/JOE_2010_o.pdf.

[7] US Department of State, *Quadrennial Diplomacy and Development Review*, 2010, www.state.gov/s/dmr/qddr/.

[8] Ibid.

At the analysis and planning levels, military and intelligence agencies have begun to study how climate change may affect the global future threat environment, focusing on US national security interests. Several recent climate security studies and programs have started to assess these national security implications, including the

- 2008 National Intelligence Assessment on the National Security Implications of Global Climate Change,
- 2010–2011 Defense Science Board Task Force on Trends and Implications of Climate Change for National and International Security,
- Minerva-funded CCAPS Program, and
- CIA, Center on Climate Change and National Security.

Direct links between conflict and climate change are tenuous in much of the academic literature because of poor environmental data, the complexity of potential relationships, and uncertainty associated with climate projections.[9,10] Much of the environmental security literature currently downplays the potential for interstate "environmental wars" but is increasingly supportive of climate-induced natural resources decline (or abundance) contributions to increased fragility in vulnerable societies, which could lead to instability and eventually conflict.[11,12,13] However, despite the lack of quantitative analysis, many international organizations and government experts are starting to qualitatively identify national security challenges as analysis progresses.

CLIMATE SECURITY CHALLENGES

In recent years, national security and climate change have been viewed in the context of direct climate change impacts, such as sea level change, floods, drought, and even drastic abrupt climate change event scenarios. Climate shifts, real or perceived, are already influencing international dialogs, and this will intensify in coming decades, particularly as impacts are (or are perceived to be) more manifest.[14] Concerns over both resource scarcity and entrée to newly accessible resources are already prompting nations to take actions to ensure access to natural

[9] Halvard Buhaug, Niles Petter Gleditsch, and Ole Magnus Theisen, *Implications of Climate Change for Armed Conflict* (Washington, DC: World Bank Group, Social Development Department, 2008, siteresources.worldbank.org/INTRANETSOCIALDEVELOPMENT/Resources/SDCCWorkingPaper_Conflict.pdf.

[10] AEPI, *Environmental Factors in Forecasting State Fragility*, June 30, 2010, www.aepi.army.mil/.

[11] Ibid.

[12] See Note 2, this chapter.

[13] Edward Miguel, Shanker Satyanath, and Ernest Sergenti, "Economic Shocks and Civil Conflict: An Instrumental Variables Approach, *Journal of Political Economy*, Vol. 112, No. 4, 2004.

[14] See Note 2, this chapter.

resources, whether energy, minerals, water, or agricultural land.[15] Although climate change is not the cause of this behavior, it may well amplify it (the so-called threat multiplier). Real and overblown concerns over natural resources critical to states' national interests may lead to the intensification of existing disputes or spur novel issues in newly accessible areas, such as the arctic.[16] Conditions that contribute to and cause mass migration (such as environmental degradation, natural disaster, and military conflict) may even spur tensions or intervention by individual countries or under international banners.[17] At a minimum, increased weather driven hazards, greater environmental stress, and augmented natural resource competition will likely result in intensified demand for humanitarian response and multilateral partnerships.[18]

Climate change will affect the natural environment in many ways that will directly involve US national security interests, including

- border and exclusive economic zone (EEZ) disputes,
- water stress,
- food production declines,
- climate augmented disasters,
- international mass migration, and
- expansion of fragility, instability, and failed states.

Border and EEZ Disputes

Instances of border disputes over natural resource access and management go back to antiquity, but they may be complicated by climate-change-facilitated access to new areas. Border, territorial waters, or exclusive economic zone (EEZ) debates are concerns with the potential of emerging arctic transit corridors and territorial claims over new natural resource discoveries.[18] Conversely, future changes to Arctic ecosystems could threaten the productivity of important and lucrative fishing industries. Climate-driven shifts in fisheries and other ecosystem services within national EEZs or international waters could become fodder for transnational disputes, particularly in the absence of ratified international conventions, such as the Law of the Sea.

[15] See Note 4, this chapter.

[16] National Academy of Sciences, *National Security Implications of Climate Change for US Naval Forces*, 2011, www.nap.edu/catalog/12914.html.

[17] Stark et. al., *Climate Change, Adaptation, and Conflict: A Preliminary Review of the Issues*, CMM Discussion Paper No. 1, USAID, October 2009.

[18] See Note 16, this chapter.

Water Stress

Soldiers from Multi-National Division - Baghdad, 1st Battalion, 63rd Combined Arms Battalion, 2nd Brigade Combat Team, 1st Armored Division, and residents of Chaka 1 work to install a solar powered water filter in Chaka 1, Lutifiyah Nahia on December 16, 2008, to bring clean water to this rural village. Photo taken by US Army, December 16, 2008.

The NIC, US National Academies of Science, and IPCC all voice strong concerns that climate change will likely degrade freshwater resources in quantity, quality, or both.[19,20] Climate change is anticipated to affect the natural hydrologic cycle. Changes in temperature and hydrological regime will certainly challenge many areas that already have and will have water concerns, particularly in the face of significant demographic shifts. For countries without sufficient water management systems, the increased populations, significant agricultural water demands (70 percent of water use in developing countries), and planned energy growth could impair economic growth and human welfare when combined with decreased precipitation, melting glaciers, or reduced snowmelt contribution upstream.[21] In areas with sufficient water, the timing of its deposition and release may change enough to potentially increase famines, floods, and fire hazards and endanger the viability of agriculture and natural ecosystems. These disruptions will also likely have transboundary effects. For example, decreased snowfall in the Himalayas can reduce glacially sourced freshwater resources downstream in India. Climate change can also cause sea level rise, which can alter existing freshwater resources. From current projections, the NIC estimates that 21 countries (with 600 million people) are currently water or cropland stressed and anticipates that the number will grow to 36 (with 1.4 billon people) by 2025.[22]

Food Production Decline

Climate shifts of temperature and precipitation will likely produce creeping changes and amplify chronic food security challenges. Through the combination of altered water resources, altered growing seasons, and increased hazardous weather, climate change has the potential to change agricultural productivity within countries. In some countries, climate change may enhance agricultural production, but this will not be the case for many, particularly where future conditions

[19] See Note 2, this chapter.
[20] See Note 17, this chapter.
[21] See Note 2, this chapter.
[22] See Note 2, this chapter.

accelerate land degradation and agricultural decline.[23] Food production and distribution are often at the nexus between environmental factors and human security domains. They are often an interaction between agricultural output (environment and economic) and distribution (socioeconomic). In addition, the rapid expansion of biofuel feedstock production, in lieu of food cultivation, could already be contributing to economic food scarcity globally.[24] Food security, or the lack of it, often goes hand in hand with population dislocation and state failures, such as in Somalia and Sudan.

Climate-Augmented Disruptions and Disasters

Droughts, floods, and hurricanes are often the favorite climate change topics with implications for national security. Because of the numerous humanitarian disasters in recent history, rapid response and recovery operations have constituted a large portion of the international community and US government's engagements over the last two decades. Despite the significant scientific uncertainty over cli-climate change's direct influence on the intensity and frequency of natural disasters (storms, floods, etc.), we can assume that climate change will be cited by many as a cause and that climactic shifts will modify the US government's natural hazards.[25] For coastal nations and megacities with growing urban populations, even modest rises in sea level could dramatically intensify the storm surge impacts of "normal" storm and hurricane events. Regardless, the demand for disaster and humanitarian response from the international community, particularly the United States and its military assets, will grow.

Staff Sgt. Ryan Knight, a soldier with U.S. Army Japan, shakes hands with a displaced Japanese citizen during the relief efforts of Operation Tomodachi at Toho Junior High School, March 31, 2011. Photo taken by US Army, March 31, 2011.

International Mass Migration

Increased natural hazards and chronic natural resource scarcities could potentially spur mass migrations.[26] Although intensified Hobbesian conditions would not de facto characterize such migrants as environmental or climate refugees, additional migration pressures can contribute to substantial human suffering and exacerbate internal and international tensions. For example, the ongoing crisis in

[23] See Note 17, this chapter.

[24] See Note 2, this chapter.

[25] See Note 17, this chapter.

[26] See Note 17, this chapter.

Darfur—with its staggering human cost and brutality—is cited as a climate-change-driven conflict with significant refugee components.[27]

Fragility, Instability, and Failed States

As discussed, much of the environmental security literature downplays the potential for interstate "environmental wars" but increasingly supports the natural resources decline (or abundance) contributions to increased fragility.[28] The NIC suggests that climate change will likely

> exacerbate resource scarcities. … Regional differences in agricultural production are likely to become more pronounced over time with declines disproportionately concentrated in developing countries, particularly those in Sub-Saharan Africa. … For many developing countries, decreased agricultural output will be devastating because agriculture accounts for a large share of their economies and many of their citizens live close to subsistence levels. … Energy and climate dynamics also combine to amplify a number of other ills such as health problems, agricultural losses to pests, and storm damage.[29]

Climate change may indeed create new natural resource disputes, but it is more likely to exacerbate existing natural resource management challenges. Climate change will certainly do more harm to vulnerable states that already lack significant resiliency or adaptive capacities. Fragile societies will have more trouble coping with the acute impacts and long-term effects on their natural resources and human environs.

OPPORTUNITIES

As discussed, state fragility concerns the relationship between the state and its citizenry, and broad market baskets of indicators generally gauge the security, political, economic, and social sectors. Highly fragile states usually mirror the list of states on instability and failed state lists.

The government has recently increased its focus on the relationship of environmental factors and natural resource sectors with fragility. In particular, DoD and development practitioners have growing concerns about the impact degrading natural resources may have on social fragility, particularly its social and economic components. Economic declines (or even insufficient growth) in a country indicate its future political instability and a worsening security situation.[30] In response, the academic community has increasingly focused research on the

[27] While controversial, Ban Ki Moon, UN Secretary General, published an Opinion piece titled "A Climate Culprit In Darfur" in the Washington Post on Saturday, June 16, 2007, www.washingtonpost.com/wp-dyn/content/article/2007/06/15/AR2007061501857.html.

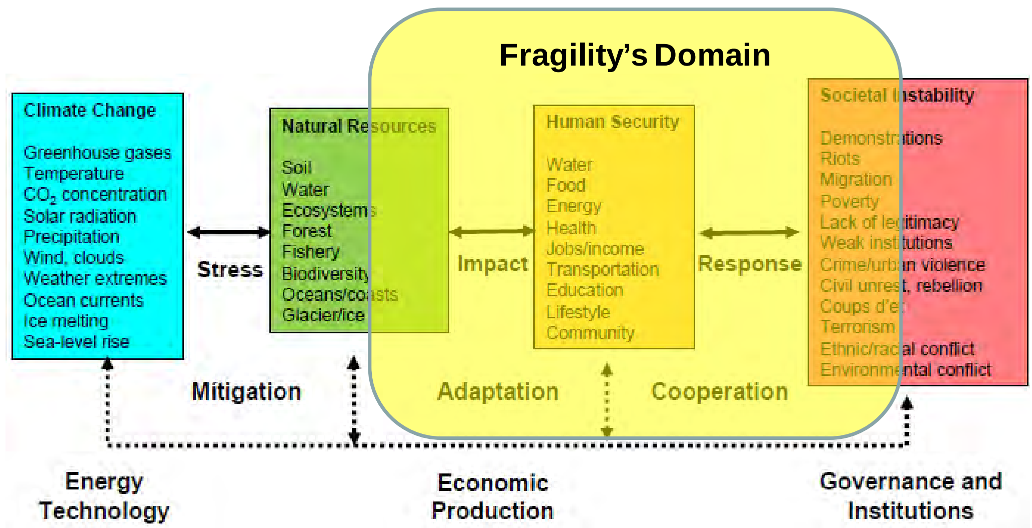
[28] See Note 10, this chapter.

[29] See Note 4, this chapter.

[30] See Note 13, this chapter.

linkages between social conflicts (rather than armed conflict), vulnerability, and climate change (Figure 6-1).

Figure 6-1. Integrated Assessment Framework of Climate-Society Interaction



Adapted from Jürgen Scheffran, "Conflicts and Instabilities in Climate-Society Interaction," International Studies Association Convention, Montreal, March 16, 2011.

Climate change's anticipated affects on water, food, and energy are likely to make countries with limited resilience or adaptive capacity even more vulnerable and fragile. Increased fragility reflects reduced government effectiveness and legitimacy, and ultimately represents national security implications associated with a slow slide toward additional weak and failed states in the future.

New climate adaptation approaches and changing national security missions introduce new challenges but also represent significant opportunities. National security interest in climate change complements the mainstreaming of natural resource and environmental factor integration with fragility approaches used by the national security community. Adaptation planning and technical transfer are expanding in the international relations and development communities, offering ample opportunities for defense-sector collaboration in HADR, mil-to-mil, etc. Climate adaptation offers a novel venue for combined operations, military engagement, and knowledge exchange. New climate adaptation programs are opportunities for the US government to leverage a synergy between fragility reduction and building greater national, regional, and community resiliency against the impacts of climate change.

Proactive government partnership, planning, and peace-building activities take on new urgency with a clearer understanding of these potential national security threats and opportunities. However, given the growing multiplicity of needs and constrained resources, smart power approaches and engagement of non-traditional agencies and capacities are necessary to effectively achieve US national security objectives. These approaches, agencies, and capacities can leverage the proposed fragility and natural resource/environmental factor analysis, monitoring, and early warning systems to inform climate security assessments and accomplish their missions.

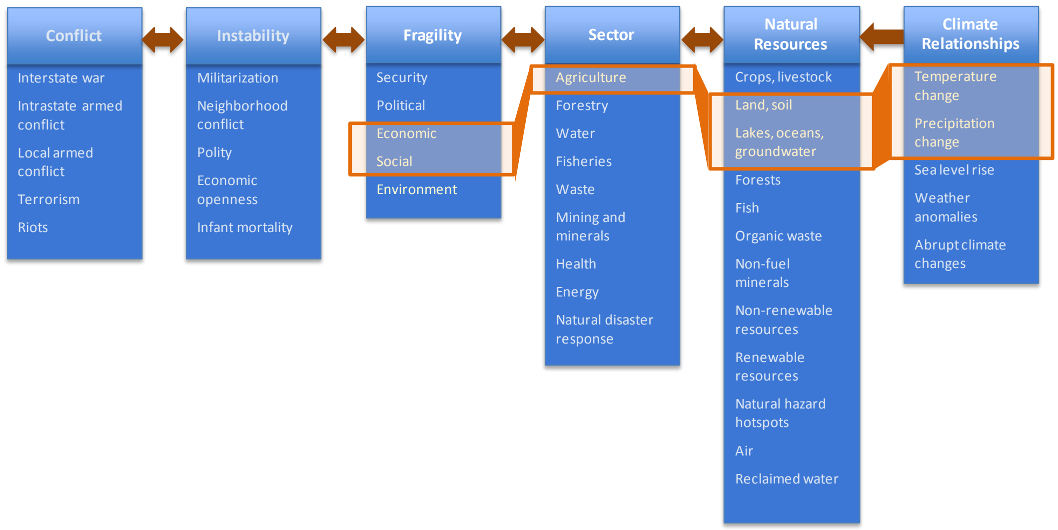
PROPOSED ARCHITECTURE'S UTILITY

Government climate security studies focus on links to social conflict and vulnerability using geospatially explicit approaches in the conflict, natural resource, and climate change arenas. Fragility and environmental change approaches closely align with most elements of climate vulnerability. The conceptual definition of vulnerability is a close yet more focused analog to fragility (Chapter 1), so we suggest that our proposed fragility and environmental early warning approach (Chapter 5) could also be leveraged to address US military strategic and operational planning needs in keeping with natural resource and climate change threat multipliers.

The affects of climate change on national security are of increasing interest to the military and intelligence communities, but we did not identify government capabilities that explicitly link and analyze the relationships between climate change, natural resources/environmental factors, and fragility in a robust, systematic manner. Such a capability is needed if climate security is to be meaningfully incorporated into the relevant government national security missions and decision-making processes.

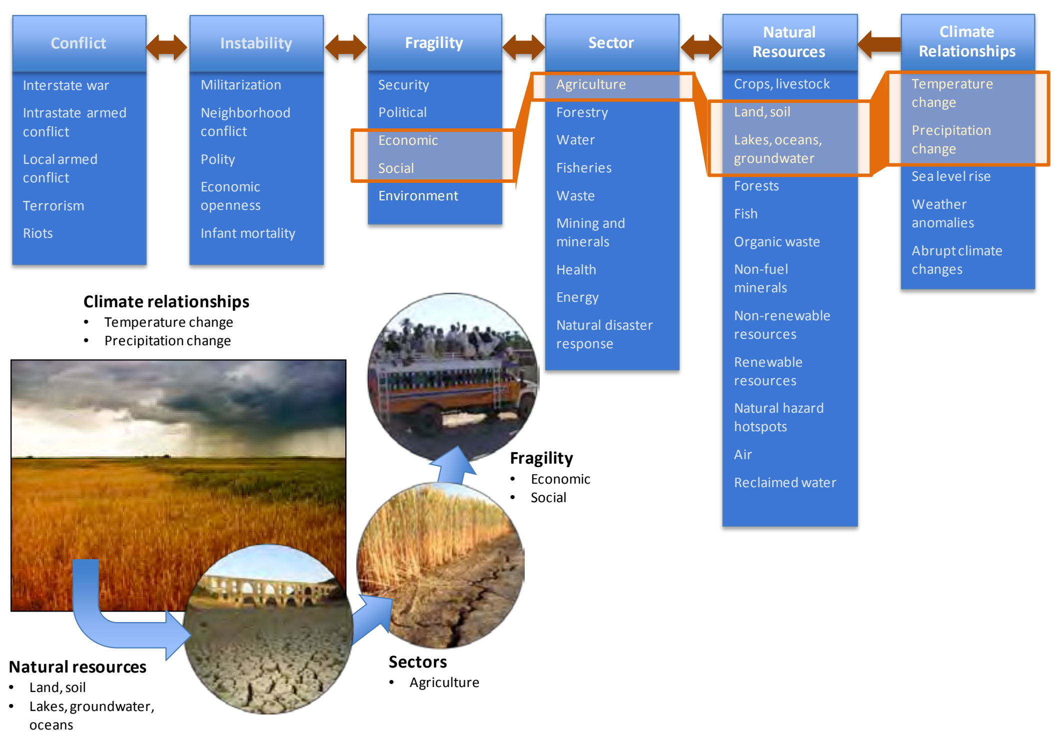
To this end, we propose to extend our fragility early warning architecture (Chapter 5) to support policymakers and analysts' understanding of the relationships between environmental factors and societal fragility (Figure 6-2). By extending this approach, national security analysts can potentially collaborate with climate specialists, within this conceptual framework and system architecture, to analyze the effects of climate change on fragility in a military mission-relevant manner.

Figure 6-2. Proposed Architecture's Extension for Climate Impact Analysis



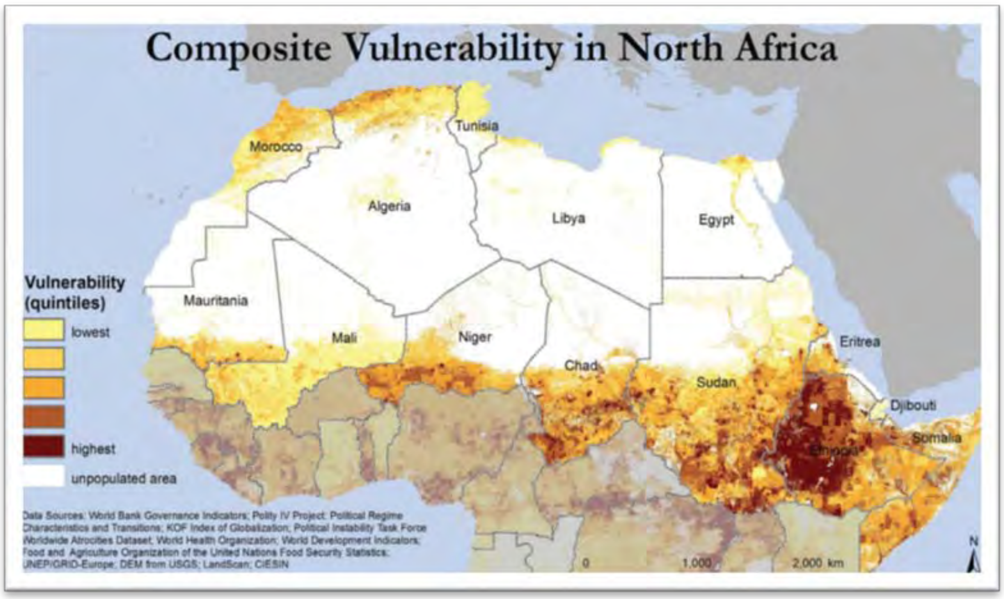
To extend this approach, we must gather projections from climate models on how climate change will affect the natural environment (Figure 6-3). These projections can then be input into the proposed architecture to help analysts understand the possible relationships between climate change and fragility.

Figure 6-3. Example of Proposed Architecture's Use for Climate Analysis



Analysts could also use the proposed architecture as an early warning system for analysis and exercises. A fragility early warning system with natural resource/environmental factor and climate modules would provide a formalized assessment approach and toolset that robustly couple climate change projections with a military mission-relevant analysis of societal fragility and would assist policymakers and analysts in identifying and mitigating highly vulnerable areas. For example, though focused on vulnerability rather than fragility, the Minerva-funded CCAPS efforts at the University of Texas at Austin have developed some useful geospatial data and analysis capabilities and products to anticipate potential climate vulnerability on the African continent (Figure 6-4).

Figure 6-4. Example of Climate Vulnerability in North Africa



Joshua W. Busby et al., *Locating Climate Insecurity: Where Are the Most Vulnerable Places in Africa*, August 2010, ccaps.robertstrausscenter.org/system/research_items/pdfs/19/original.pdf?1286296660.

In addition, these products could use the proposed fragility architecture and products to inform and develop realistic scenarios and planning exercises. For example, country analysts could review how climate change will impact the growing season in Ghana by changing rainfall patterns and temperatures. They could then visualize how the altered growing season might lead to local political and economic dynamics that could eventually impact the country's fragility. Such grounded scenarios could be used to draw up smart power bilateral engagement, theater security cooperation, and climate adaptation plans as well as program the necessary resources and capabilities.

This proposed approach would leverage the national security relevant concept of fragility to reduce the "leap of faith" in making connections between conflict and climate. While still a nascent analysis approach, engagement and collaboration between national security policymakers, analysts, fragility researchers, and climate specialists can help bridge the current conceptual and technical gaps. The extension of the proposed fragility and natural resource architecture to climate aspects is a step toward operationalizing climate security and managing its risks.

Chapter 7
Conclusions and Recommendations

The Army, DoD, and the US government have considerable capacity to use information on natural resources, environmental change, and fragility to inform decision making and enhance execution of their national security missions. The Army's forward-deployed presence on frontiers and borders often places it in direct contact with fragile states as well as those that have weakened to the point of instability, failure, or conflict. The military possesses national security professionals, a chain of command, communications capabilities, and transportation and mobility assets that can and are often called upon to support whole-of-government responses and interventions, particularly in complex environments. In particular, the military has highly relevant mission responsibilities, including mil-to-mil engagement, HADR,[1] and initial public-service provisioning in SSTR situations. Though not exhaustive, this list of missions and their related commands are prime opportunities for DoD, along with other US government agencies, to examine immediate and policy-relevant opportunities for smart power planning, collaboration, decision making, and action. Moreover, by seizing these opportunities and strengthening these mission capabilities, the Army and DoD are ultimately supporting the achievement of our national military objectives to "deter and defeat aggression" and "strengthen international and regional security."

This report is a starting point for mapping concepts, needs, capabilities, and gaps to enable this necessary upgrade to the US national security analytical and decision-making toolkit. To this end, we identify initial Army user needs and technical resources relevant to conflict, instability, and fragility analysis, early warning, and enablement and where natural resource and environmental factor integration may hold challenges and opportunities to shape the global future security environment. We focus on current and emerging military mission needs while identifying US government data, analysis, modeling, and tool capabilities potentially available to support these missions using the proposed conceptual framework.

The majority of the identified approaches, tools, and early warning systems are oriented toward country instability and conflict. Aside from the noted examples, most do not yet address fragility, do not incorporate natural resources, and sometimes use divergent conceptual lexicons. Conversely, research increasingly focuses on social conflict and vulnerability, increased policymaker and practitioner urgency to address fragility, and natural resource and climate challenges. These challenges are, however, linked with opportunities in the emergence of geospatially enabled government capabilities, which can provide fragility analysis, identify

[1] While worthwhile and noble missions in their own right, both mil-to-mil and HADR missions fall under and directly support the National Military Objective to "Deter and Defeat Aggression."

early warning signposts, and inform joint military-civilian mission planning, decision making, and execution in an interagency context. Efforts to understand fragility in relation to the US military mission and energy and climate change vulnerability in the US development community are moving in intersecting directions. Continued efforts to identify common concepts (conflict, instability, fragility, vulnerability, resilience, and adaptation) and efforts to socialize conceptual areas of interagency agreement will help enable systematic coordination in support of robust analysis processes, relevant early warning systems, informed policy decisions, and enhanced government unity of effort in achieving US national security interests.

On the basis of our findings, we recommend the following:

- Further develop and socialize the fragility and environmental change early warning system concept to support Army contingency planning, mission situational awareness, and regional security cooperation engagement, including the related policy implications.
- Devote Army, DoD, and government efforts to researching and conceptualizing modular hybrid early warning system capabilities for state and social fragility that integrate environmental and natural resource factors and leverage existing qualitative and quantitative data analysis capabilities.
- Explore a regional COCOM pilot of geospatial and computational social science approaches, leveraging mission-relevant examples of fragility and natural resources interactions (perhaps grounded in forthcoming UNEP case studies), where not already reflected in Army or DoD analytical frameworks.
- Study relevant instances of Army, DoD, and interagency decision making and how access to data, analysis, and early warning produced better and less costly proactive decisions.
- Engage the Army, DoD, and external technical communities to identify and pursue opportunities to collaborate in a community of practice, leverage resources, and adapt analysis and early warning systems to address sector, natural resource, and climate factors, where feasible.

Over the next decade, DoD mission capabilities and interagency processes that reflect the realities of the future global security environment will better serve our national security. The Army is not only learning and applying the lessons of active asymmetric warfare and SSTR operations, but also preparing doctrine and capabilities to fight the next war, which is more about winning the peace in the face of intensified human security challenges.

Appendix A
Points of Contact and Potential Resources

Name	Organization	Category
Mr. Steven Hearne	Army Environmental Policy Institute	Task COR
Mr. Bill Goran	US Army Corps of Engineers (USACE), Engineer Research and Development Center (ERDC)	Army Technical Resource
Mr. Jim Westervelt	USACE, ERDC	
Mr. Justin Pummell	USACE, Geographic Information Systems Program, Geographer	
Mr. Joel Schlagel	USACE, Institute for Water Resources	
Dr. Jerry Delli Priscolli	USACE, International Water Resource Institute	
Mr. Mark Hainsey	USACE, Headquarters	
Ms. Sarah Kopczynski	USACE, Cold Regions Laboratory (CRREL) / on detail to USACE Headquarters, Washington, DC	
Ms. Renee R. Chapman	USACE, Headquarters	
Mr. Jamal Beck	US Army Geospatial Center (AGC)	
Mr. Robert Burkhardt	US AGC	
Ms. Renee G. Carlucci	Center for Army Analysis (CAA), Force Strategy Division	
Mr. Greg Andreozzi	CAA, Force Strategy Division	
Ms. Megan Malone	CAA, Conflict Analysis Division	
Dr. Robert E. (Bert) Davis	USACE, ERDC & Strategic Multi-Layer Assessment	
Ms. Brenda Wyler	US Army, Headquarters, Department of the Army (HQDA) 3/5/7, G-3 Stability Operations	Army User
Mr. Joe Drach	US Army, HQDA 3/5/7, G35, Army International Affairs Division, Army International Activities	

Name	Organization	Category
Mr. Dana Dillon	US Army, HQDA, G2	
COL Wendell Moore	US Army, HQDA	
Mr. Kurt Kinnevan	US Army, HQDA 3/5/7	
Ms. Michelle Harlan	US Army Security Assistance Command	
Ms. Karen Finkenbinder	Army Peacekeeping and Stability Initiative	
COL David Carstens	Senior Service College Fellow, Formerly of Central Intelligence Agency Center on Climate Change and National Security	
Dr. John Salerno	Air Force Research Laboratory, Rome Research Site	Air Force Technical Resource
Ms. Courtney St. John	US Navy, Office of the Oceanographer, Task Force Climate Change	Navy User
LTC Shannon Beebe	Formerly of Defense Security Cooperation Agency	Department of Defense Technical Resource
Dr. Barbara Sotirin	Joint Staff J-5 (SES); Formerly of USACE, Headquarters;	
Dr. Hriar Cabayan	Office of the Secretary Defense (OSD), OSD-Acquisition, Technology and Logistics & Strategic Multi-Layer Assessment effort	
Ms. Deborah Pyle	Joint Staff J-3	
Dr. Sean O'Brian	Formerly of Defense Advanced Research Projects Agency, Information Processing Techniques Office	
Ms. Karen Thomas	National Geospatial-Intelligence Agency	
Mr. James Pugel	National Defense Intelligence College, Defense Intelligence Agency, and Peace Research Institute Oslo	
Ms. Kathleen Hicks	Deputy Under Secretary of Defense for Strategy, Plans, and Forces	DoD User
Mr. Steven W. Ayers	Joint Staff, J-2, Global Warning Enterprise	
CAPT John Kliem	Joint Staff, J-4	
LTC Reginald Robinson	Joint Staff, J-5	
Deane E. Swickard	US African Command (USAFRICOM), IKD-Knowledge Development Division	

Name	Organization	Category
Mr. Art Kolodziejski	USAFRICOM	
Mr. Robert Pace	USAFRICOM	
Ms. Myrna Lopez	US Southern Command (USSOUTHCOM), J-9 Partnering Division	
Ms. Eyrn Robinson	USSOUTHCOM and Department of Energy	
Mr. Michael Brown	US European Command	
LTC Douglas Long	US Central Command	
LTC Paul M. Schimpf	Office of the Secretary Defense Under Secretary of Defense (USD) (Policy)	
Mr. Sam Binkley	Office of the Secretary Defense USD (Policy)	
COL Chris Atteberry	Office of the Secretary Defense USD (Policy)	
LTC Joe Knott	National Guard Bureau	
Dr. Geoffery D. Dabelko	Woodrow Wilson Center for Scholars, Environmental Change and Security Program	USG Technical Resource
Dr. S. Tjip Walker	US Agency for International Development (USAID), Formerly of the Office of Conflict Management and Mitigation (CMM)	
Ms. Cynthia Brady	USAID, CMM	
Mr. Kirby Reiling	USAID, CMM	
Ms. Elisabeth Dallas	USAID, CMM	
Mr. Oscar A.Carrasco	USAID, Humanitarian Information Unit (HIU)	
Gary Eilerts	USAID, Famine Early Warning Systems Network	
Dr. Chad Briggs	Air University, Formerly of GlobalEESE	
Dr. Molly E.Brown	National Aeronautics and Space Administration, Goddard Space Flight Center, Earth Science	
Dr. Roger S. Pulwarty	National Oceanic and Atmospheric Administration, Climate Program Office and Earth System Research Laboratory, National Integrated Drought Information System	

Name	Organization	Category
Dr. Cynthia Irmer	U.S. Department of State, Office of the Coordinator for Reconstruction and Stabilization, Conflict Prevention Office	
Dr. Aaron Salzburg	US Department of State	
Dr. David Roberts	US Department of State, OES, Water Team	
GEN Richard Engel	National Intelligence Council	

Appendix B
List of Outreach Meetings

Identifying opportunities for early warning systems and approaches that incorporate environmental factors into instability-fragility analysis requires engagement with Army, DoD, and interagency stakeholders to develop a common conceptual “operating system.” Throughout the course of this study, a series of briefings, meetings, and workshops were held to better inform the development of resources that are supportive of US Army and DoD strategic operational planning needs. Below summarizes the outreach meetings that occurred during the course of this study.

BRIEFINGS		
Presentation	**Date**	**Description**
Environmental Factors in Forecasting State Fragility, Steven Hearne and Jeremey Alcorn	11/23/10	♦ Briefing to US Agency for International Development (USAID) Office of Conflict Management and Mitigation (CMM), Washington, DC
	12/06/10	♦ Briefing to Center for Army Analysis, Washington, DC
	01/05/11	♦ Briefing to Center for International Development and Conflict Management, Crystal City, VA
	02/28/11	♦ Briefing to Mr. Dana Dillon, US Army G-2, Crystal City, VA
	04/07/11	♦ Briefing with Dr. Geller of Mason University, Fairfax, VA
	04/20/11	♦ Briefing with Ms. Parthemore of Center for a New American Security, Crystal City, VA
	05/3/11	♦ Representative, US Intelligence Community, McLean, VA
	05/6/11	♦ LTC Shannon Beebe, Defense Security Cooperation Agency, US Army, Crystal City, VA
	05/25/11	♦ Dr. Cynthia Irmer, US Department of State

ADDITIONAL MEETINGS	
Date	**Description**
09/14/10	♦ Teleconference with Nadja Turek and Steve Phipps of Woolpert
11/18/10	♦ Teleconference with Jim Pugel of the Defense Intelligence Agency
01/11/11	♦ Teleconference with Dr. Jennifer Hazen of Climate Change and African Political Stability (CCAPS) Research Program
01/25/11	♦ Teleconference with Dr. Clionadh Raleigh of CCAPS and Peace Research Institute Oslo
02/01/11	♦ Teleconference with Dr. Joshua Busby of CCAPS and University of Texas at Austin
09/08/11	♦ Teleconference with Dr. John Salerno, Air Force Research Laboratory, Rome Research Site
WORKSHOPS ATTENDED	
Date	**Description**
09/18-09/10/10	♦ US Army Corps of Engineers (USACE)/Construction Engineering Research Laboratory (CERL), Proactive Peace Building with Natural Resources Assets: Analysis of Historical Controversies and Conflicts to Inform Future Actions, Chicago, IL
12/14/10	♦ Army Environmental Policy Institute, Using Sustainability to Build Stability: Water Security as an Engagement Tool, Washington, DC
01/26/11	♦ USAID/CMM, Conflict, Fragility, and the Environment: Experts Workshop, Arlington, VA
02/14-15/11	♦ USACE/CERL, Proactive Peace Building with Natural Resource Assets Workshop #2, Arlington, VA
05/12/11	♦ National Defense Industrial Association Environment, Energy and Sustainability Symposium, New Orleans, LA
05/16-17/11	♦ University of Texas at Austin, Mapping and Modeling Climate Security Vulnerability, Austin, TX
06/14/11	♦ The Forum on Earth Observations V: Creating a National Strategy for Environmental Intelligence, Washington, DC

Appendix C
Intra-Army Working Group Draft Charter

INTRA-ARMY WORKING GROUP ON INSTABILITY AND FRAGILITY ASSESSMENT AND MISSION ENABLEMENT

Mission Statement and Goals

This Intra-Army Working Group (IAWG) will develop a common conceptual "operating system" for instability and fragility assessment (including natural resources linkages) and explore its potential contributions to the Army's full-spectrum stability, security, transition, and reconstruction (SSTR) and military-to-military (mil-to-mil) missions.

The goals for convening this IAWG are to

- examine instability and fragility technical approaches,
- evaluate instability and fragility's relationship to mission at all levels,
- solicit end-user requirements and applications at all levels,
- identify data source and analysis challenges and opportunities, and
- discuss relevant integration approaches for tabular, geospatial, and quantitative-qualitative data and temporally explicit approaches.

Workgroup Background and Description

With the release of National Security Presidential Directive 44, 2010 Quadrennial Defense Review, Department of Defense Directive 3000.5, and sustainability commitments, the Army is increasingly expected to develop and utilize enhanced means to integrate non-traditional factors—such as economics, energy, and natural resources (renewable and non-renewable)—into its strategic assessment approaches and operational level "peace-building" opportunity assessments. Over the past decade, experience in theater has reinforced the need to better facilitate unity of effort with non-defense government entities and non-governmental organizations to meet national security mission objectives while applying differing world views and lexicons.

This IAWG specifically seeks to develop common operating concepts and a lexicon for instability and fragility assessment and to explore these approaches' potential contributions to supporting the Army's mission across the full spectrum of operations. To this end, this effort intends to leverage recent progress in developing national security concepts, such as instability, fragility, and human security, which enable better unity of effort with mission partners. The IAWG will also discuss the technical approaches, data, and integration of these concepts into existing early warning tools or engagement processes in ways that help meet existing and emerging SSTR mission requirements at all levels. Examples include the following:

- Army International Office and G3 fragility monitoring and peace-building approaches
- Combatant command (COCOM) mil-to-mil environmental engagement planning
- COCOM partner emergency response capabilities planning
- In-theater counter insurgency strategy opportunity assessments.

By developing a doctrinally compatible "common operating system" for these concepts, the Army can develop new open-architecture approaches and tools. These new capabilities can enable intra-Army and interagency collaborative efforts that support proactive and integrated "whole-of-government" state instability and fragility management strategies as demanded by the 2010 QDR and in-theater realities.

IAWG outputs will be used to develop recommendations that support Army strategic and operational planning needs, particularly in emerging mission-relevant natural resource (renewable and non-renewable), environmental, and climate shock threat multipliers. More immediately, such outcomes could also provide new options for joint combatant commanders in theater (Afghanistan, for example) to better coordinate and integrate with Department of State and US Agency for International Development SSTR efforts.

The IAWG is not mandatory and does not provide any official representation for any particular Army commands or organizations. The IAWG will continue as long it furthers its mission and goals, participants obtain value from its activities, and their organizations concur with their participation.

Appendix D

Inter-Agency Forum on State Instability and Fragility Approaches and Natural Resources

MISSION STATEMENT

This Inter-Agency Forum will advance US government adoption of a common conceptual "operating system" for instability and fragility assessment, the integration of natural resource (renewable and non-renewable) and environmental factors, and the exploration of potential approaches supportive of "whole-of-government," defense, diplomacy, and development aims.

FORUM PURPOSE

This Inter-Agency Forum will provide a focused venue for informal exchange and discussion, across agencies, for sharing concepts, approaches, data, tools, and expertise supportive of whole-of-government, defense, diplomacy, and development missions across the US government. The desired exchanges of information are envisioned to include

- existing instability and fragility conceptual and technical approaches;
- common operating system concepts and lexicon development;
- data source and analysis integration challenges and opportunities;
- integration approaches for tabular, geospatial, and quantitative-qualitative data and temporally explicit approaches;
- fragility's integration utility for natural resource (renewable and non-renewable) and environmental factors, including climate change;
- gaps and barriers for use or relevance within agencies at all levels; and
- common approaches and coordination demonstrations.

This forum is not official and does not provide any official representation for the participating agencies. The forum will continue as long as participants obtain value from forum activities and their organizations concur with their participation.

Appendix E
Data Matrix

The following matrix summarizes the major fragility-related, natural resource, and environmental data sources identified through the course of the study. Please note that these data sources vary widely in their resolution, extent, and domains.

Category	Indicator	Name/Citation	Data type	File Type	Metadata Available	Resolution	Extent	Year Created	Data Years Available	Data Periodicity	Organization	Country of Origin	Source	Description	Availability	URL
Agriculture	Crop production, yield, and area harvested	Agro-MAPS (Mapping of Agricultural Production Systems)	Tabular	CSV, DBF, XML	Yes	Various, down to subnational scale	Regional, national, subnational	2002	Various, ranges from 1970 to 2004	Irregular	Food and Agriculture Organization of the United Nations, International Food Policy Research Institute, Center for Sustainability and the Global Environment (SAGE) at the University of Wisconsin-Madison	Italy, USA	Multiple sources	Global spatial database of agricultural land-use statistics. This database contains statistics on primary food crops, aggregated by subnational administrative districts, on crop production, area harvested and crop yields. Data for more than 130 countries, from seven geographical regions (Africa, Asia, Near East in Asia, Latin America and the Caribbean, North America, and Oceania) and representing approximately 92 percent of the world's land surface, are currently available in Agro-MAPS.	Must submit contact information and intended use of data to obtain data.	http://www.fao.org/landandwater/agll/agromaps/interactive/page.jspx
Agriculture	Crop yields, crop suitability analyses, land cover, and climate sensitivity	Agro-ecological Zoning System (AEZ), Global AEZ (GAEZ)	Tabular, Image	MS Excel, BMP, JPEG, HTML	Yes	Various, down to nation-state scale	Global, regional, national	2000	Various	Various	Food and Agriculture Organization of the United Nations	Italy	Multiple sources	The main system for land resource assessment is FAO's agro-ecological zoning (AEZ) methodology and supporting software packages for application at global, regional, national and sub-national levels. AEZ uses various databases, models and decision support tools.	Free	http://www.iiasa.ac.at/Research/LUC/GAEZ/index.html
Agriculture	Global soils	Fischer, G., F. Nachtergaele, S. Prieler, H.T. van Velthuizen, L. Verelst, D. Wiberg, 2008. Global Agro-ecological Zones Assessment for Agriculture (GAEZ 2008). IIASA, Laxenburg, Austria and FAO, Rome, Italy.	Geospatial (raster)	MS Access, BIL	Yes	30 arc-sec	Global, regional, national	2009	Not well defined	None	Food and Agriculture Organization of the United Nations, International Institute for Applied Systems Analysis	Italy, Austria	Multiple sources	The HWSD is a 30 arc-second raster database with over 16,000 different soil mapping units that combines existing regional and national updates of soil information worldwide (SOTER, ESD, Soil Map of China, WISE) with the information contained within the 1:5 000 000 scale FAO-UNESCO Soil Map of the World (FAO, 19711981). Reliability of the information contained in the database is variable: the parts of the database that still make use of the Soil Map of the World such as North America, Australia, West Africa and South Asia are considered less reliable, while most of the areas covered by SOTER databases are considered to have the highest reliability (Central and Southern Africa, Latin America and the Caribbean, Central and Eastern Europe).	Free. Data download / compatibility issues.	http://www.fao.org/nr/land/soils/harmonized-world-soil-database/download-data-only/en/
Agriculture	Irrigated areas	Global Irrigated Area Map (GIAM) Version 2.0	Image	TIFF, JPEG	Not well defined	Not well defined	Global	2006-2007	Developed from time-series data ranging from 1961 - 2003	Yes, but not well defined	International Water Management Institute (IWMI)	Sri Lanka	Multiple sources	The IWMI GIAM is derived from a great variety of remote sensed data at different geographical and time scales. It provides 28 unique irrigated area classes of the World, with 10 surface water classes and 18 groundwater\conjunctive use classes. The characteristic spectral and time-series signatures are attached for each of the 28 classes. These characteristics indicate whether the area is single, double or continuously cropped. The GIAM products are produced using time-series data of: (a) AVHRR 10-km monthly from 1997-1999, (b) SPOT 1-km monthly for 1999, (c) GTOPO30 1-km elevation, (d) CRU 50-km grid monthly precipitation from 1961-2000, (e) AVHRR derived 1-km forest cover, and (f) AVHRR 10-km skin temperature. In addition JERS-SAR data was used for the African and South American rainforests.	Free. Data download / compatibility issues.	http://www.iwmigiam.org/info/gmia/default.asp
Agriculture	Irrigated areas, irrigation cropping pattern zones, dams, rivers, hydrological basins, soil moisture, precipitation, and evapotranspiration	AQUASTAT	Geospatial (vector and raster)	ArcView GIS Shapefile, ASCII	Yes	Various, including 10 arc-sec and 30 arc-sec	Global, regional (Africa and South East Asia)	1999-2006	Various, ranges from 1958 - 2010	Various, from monthly to 5 years	Food and Agriculture Organization of the United Nations	Italy	Multiple sources	Provides 13 hydrologic spatial datasets. The datasets focus on hydrological basis, rivers, dams, inland water bodies, and irrigation cropping pattern zones in Africa; hydrological basins in South East Asia; and global soil moisture, monthly precipitation, monthly reference evapotranspiration, and irrigated areas.	Free, through FAO GeoNetwork.	http://www.fao.org/nr/water/aquastat/gis/index2.stm
Agriculture	Irrigated water use	Irrigation water withdrawals	Geospatial (raster), Image	ASCII, ArcInfo E00, JPEG	Yes	30-min grid	Global	2005	2000	None	Water Systems Analysis Group, University of New Hampshire	USA	Multiple sources	Gridded field of irrigation withdrawals for 2000 (in millions of cubic meters per year) at 30 minute (latitude by longitude) resolution (Vorosmarty et al., 2005). Country-level irrigation withdrawals per capita (World Resources Institute, http://earthtrends.wri.org/) were multiplied by country-level population to estimate irrigation withdrawals for each country. Country-level irrigation withdrawals were distributed over irrigated lands (aggregated from Doll and Siebert, 2000) prorated on estimated irrigation need. Irrigation need was computed as the difference between potential evapotranspiration (PET, which represents the crop water requirements under optimal conditions) and actual evapotranspiration (AET). PET was estimated using the physically-based function of Shuttleworth and Wallace (1985), which is a modification of the standard Penman-Monteith PET equation. AET was estimated by the Water Balance Model (Vorosmarty et al., 1998).	Free	http://wwdrii.sr.unh.edu/download.html
Agriculture	Irrigation	AquaCrop	Model	Proprietary format	Yes	Not well defined	Global	2011	Not well defined	Not well defined	Food and Agriculture Organization of the United Nations	Italy	Multiple sources	AquaCrop is the FAO crop-model to simulate yield response to water of several herbaceous crops. It is designed to balance simplicity, accuracy and robustness, and is particularly suited to address conditions where water is a key limiting factor in crop production. AquaCrop is a companion tool for a wide range of users and applications including yield prediction under climate change scenarios.	Free, but requires software download.	http://www.fao.org/nr/water/aquacrop.html
Agriculture	Irrigation-equipped area	Irrigation-equipped area	Geospatial (raster), Image	ASCII, ArcInfo E00, JPEG	Yes	30-min grid	Global	2000	1995	None	Water Systems Analysis Group, University of New Hampshire	USA	Döll, P., Siebert, S. (2000): A digital global map of irrigated areas. ICID Journal, 49(2), 55-66.	Area equipped for irrigation. The period depicted is approximately 1995 and was derived Doll and Siebert (2000) from a combination of administrative unit and geospatial data. Downloadable file was developed by aggregating the original 5 minute (lat X long) resolution dataset to 30 minute (lat X long) resolution.	Free. Data download / compatibility issues.	http://wwdrii.sr.unh.edu/download.html

Category	Indicator	Name/Citation	Data type	File Type	Metadata Available	Resolution	Extent	Year Created	Data Years Available	Data Periodicity	Organization	Country of Origin	Source	Description	Availability	URL
Agriculture	Pesticide sales	World Pesticides to 2014 - Demand and Sales Forecasts, Market Share, Market Size, Market Leaders	Report	PDF, HTML	Yes	Nation-state	Global, regional, national	2011	1999, 2004, 2009	Irregular	Fredonia Group	USA	Multiple sources	This study analyzes the $45 billion world pesticide industry. It presents historical demand data for the years 1999, 2004 and 2009, and forecasts for 2014 and 2019 by product (e.g., herbicides, insecticides, fungicides), market (e.g., wheat, corn, rice, soybeans, consumer, commercial), world region and for 39 major countries. The study also considers market environment factors, details industry structure, evaluates company market share and profiles 42 industry participants, including Bayer, Syngenta and BASF.	For purchase at $5,800.	http://www.freedoniagroup.com/World-Pesticides.html
Agriculture	Rainfed cropland areas	Global Map of Rainfed Cropland Areas (GMRCA)	Image	TIFF, JPEG	Not well defined	Not well defined	Global	2007	Developed from time-series data ranging from 1961 - 2003	Yes, but not well defined	International Water Management Institute (IWMI)	Sri Lanka	Multiple sources	Rainfed croplands meet about 60 percent of the food and nutritional needs of the World's population, are backbone of the marginal or subsistence farmers, and are increasingly seen as better alternative to irrigated agriculture as a result of its environmental friendliness and sustainability over long time periods. Tracking changes in spatial distribution and changing patterns of rainfed croplands is essential for understanding and planning food and nutritional demands of expanding populations of the World.	Free. Data download / compatibility issues.	http://www.iwmigiam.org/info/gmia/default.asp
Agriculture	Water consumption for irrigation	GWSP Digital Water Atlas (2008). Map 15: Water Consumption for Irrigation (V1.0). Available online at http://atlas.gwsp.org.	Geospatial (vector)	ArcView GIS Shapefile	Yes	0.5° x 0.5°	Global	2008	Various, ranges from 1961-1990	Annual	Water Systems Analysis Group, University of New Hampshire	Germany	Center for Environmental Systems Research (CESR), Kassel	Mean annual consumptive water use for irrigated crops during the climate normal period (1961-1990). The map of water consumption for irrigation emphasizes the main irrigation areas of the world. Highest irrigation water consumption is located in areas with the high density of irrigation projects.	Data use limitations. Available online with registration.	http://wiki.gwsp.org/joom/index.php?option=com_content&task=blogcategory&id=34&Itemid=63
Administrative and Political Boundaries, Agriculture and Livestock, Applied ecology, Biological and Ecological Resources, Climate and Agroclimatology, Fisheries, Forestry, Hydrology and Water Resources, Land Cover and Land Use, Population and Socio-Economic Indicators, Soils and Soil Resources, and Topography.	Multiple types	FAO GeoNetwork	Geospatial, Tabular, Map, Image	Multiple types	Yes	Various	Global, regional, national	Various	Various	Various	Food and Agriculture Organization of the United Nations	Italy	Multiple sources	GeoNetwork open source allows researchers to easily share geographically referenced thematic information between different organizations. It provides Internet access to interactive maps, satellite imagery and related spatial databases.	Free	http://www.fao.org/geonetwork/srv/en/main.home
Agriculture, Atmosphere, Biology, Demographic, Elevation, environment, Geology, Health, Inland Water, Oceans	Multiple types	Geospatial One-Stop (geodata.gov)	Geospatial, Tabular	Multiple types	Yes	Various	USA focus	Various	Various	Various	Federal Office of Management and Budget (OMB)	USA	Multiple sources	Geospatial One-Stop is a GIS portal that serves as a public gateway for improving access to geospatial information and data under the Geospatial One-Stop e-government initiative. Geospatial One-Stop is one of 24 e-government initiatives sponsored by the OMB to enhance government efficiency and to improve citizen services. Geospatial One-Stop makes it easier, faster, and less expensive for all levels of government and the public to access geospatial information.	Free	http://gos2.geodata.gov/wps/portal/gos
Agriculture, Atmosphere, Biosphere, Climate Indicators, Cryosphere, Human Dimensions, Land Surface, Oceans, Paleoclimate, Water	Multiple types	Global Change Master Directory (GCMD)	Multiple types	Multiple types	Yes	Various	Global, regional, national, subnational	Various	Various	Various	National Aeronautics and Space Administration (NASA) Goddard Space Flight Center	USA	Multiple sources	The GCMD holds more than 25,000 Earth science data set and service descriptions, which cover subject areas within the Earth and environmental sciences. The project mission is to assist researchers, policy makers, and the public in the discovery of and access to data, related services, and ancillary information (which includes descriptions of instruments and platforms) relevant to global change and Earth science research. The GCMD is one of the largest public metadata inventories in the world. The GCMD's primary responsibility is to maintain a complete catalog of all NASA's Earth science data sets and services.	Free	http://gcmd.gsfc.nasa.gov/index.html
Agriculture, Climate, Land, Population, Water	Agriculture, climate, land, population, water	World Water Development Report II: Indicators for World Water Assessment Programme	Geospatial (raster), Image	ASCII, ArcInfo E00, JPEG	Yes	Various, down to regional scale	Global, regional (Africa, South America, pantropical)	Various	Various, primarily around 2000	Various	Water Systems Analysis Group, University of New Hampshire	USA	Multiple sources	The UNH Water Systems Analysis Group has developed a compendium of Earth System and socio-economic databases describing the current state of global water resources, including associated human interactions and pressures. The group has integrated a wide array of satellite-derived and land-based monitoring products from around the world with regional and country-level socio-economic data. The Group has been committed to the wide dissemination of our data products, for example the global RivDIS data sets derived from the UNESCO Discharge of Selected Rivers of the World series, as well as regional applications for South America (R-HydroNET and LBA-HydroNET on behalf of UNESCO-ROSTLAC) and across the pan-Arctic (R-ArcticNET and Arctic-RIMS, the largest such data bases available worldwide).	Free	http://wwdrii.sr.unh.edu/index.html
Air Pollution	CH4 emissions (from fossil fuels, transport, total)	Emissions of CH4	Tabular	CSV, HTML	Yes	Nation-state	Regional, national	2007-2011	Various, ranges from 1990-2008	None	United Nations Environment Programme (UNEP)	Kenya, multiple	National Reports, United Nations Framework Convention on Climate Change (UNFCCC)	National figures only include data from UNFCCC Greenhouse Gas Inventory (GHG) Annex I Parties. These inventory data are provided in the national communications under the Convention by Annex I and non Annex I Parties, and in addition Annex I Parties submit annual national greenhouse gas inventories.	Free	http://geodata.grid.unep.ch/results.php

Category	Indicator	Name/Citation	Data type	File Type	Metadata Available	Resolution	Extent	Year Created	Data Years Available	Data Periodicity	Organization	Country of Origin	Source	Description	Availability	URL
Air Pollution	CH4 emissions from agriculture	Emissions of CH4-from Agriculture (Model Estimations) TNO and RIVM	Tabular	CSV, HTML	Yes	Nation-state	Regional, national	2007	Various, ranges from 1970-2000	None	United Nations Environment Programme (UNEP)	Kenya, multiple	National Reports, United Nations Framework Convention on Climate Change (UNFCCC)	National figures only include data from UNFCCC Greenhouse Gas Inventory (GHG) Annex I Parties. These inventory data are provided in the national communications under the Convention by Annex I and non Annex I Parties, and in addition Annex I Parties submit annual national greenhouse gas inventories.	Web accessible	http://geodata.grid.unep.ch/results.php
Air Pollution	CH4 emissions from all anthropogenic sources	Emissions of CH4 from all anthropogenic sources	Geospatial (raster), Image	ASCII, ArcInfo E00, BIL, TIF	Yes	Not well defined	Global, regional	2002	1990	None	United Nations Environment Programme (UNEP)	Kenya, multiple	Multiple sources	A global emissions source database called EDGAR has been developed jointly by TNO and RIVM to meet the urgent need of atmospheric chemistry and climate modelers and the need of policy-makers. The EDGAR database was to estimate the annual emissions of direct and indirect greenhouse gases (CO2, CH4, N2O; CO, NOx, non-methane VOC; SO2), including ozone-depleting compounds (halocarbons) for 1990 on a regional and grid basis.	Web accessible	http://geodata.grid.unep.ch/results.php
Air Pollution	Emissions of CO	Emissions of CO (total)	Tabular	CSV, HTML	Yes	Nation-state	Regional, national	2011	Various, ranges from 1990-2008	None	United Nations Environment Programme (UNEP)	Kenya, multiple	Multiple sources	National figures only include data from UNFCCC Greenhouse Gas Inventory (GHG) Annex I Parties. These inventory data are provided in the national communications under the Convention by Annex I and non Annex I Parties, and in addition Annex I Parties submit annual national greenhouse gas inventories.	Web accessible	http://geodata.grid.unep.ch/results.php
Air Pollution	Emissions of GHGs (from agriculture, industrial processes, transport, and waste)	Emissions of GHGs	Tabular	CSV, HTML	Yes	Nation-state	Regional, national	2011	Various, ranges from 1990-2008	None	United Nations Environment Programme (UNEP)	Kenya, multiple	National Reports, United Nations Framework Convention on Climate Change (UNFCCC)	National figures only include data from UNFCCC Greenhouse Gas Inventory (GHG) Annex I Parties. These inventory data are provided in the national communications under the Convention by Annex I and non Annex I Parties, and in addition Annex I Parties submit annual national greenhouse gas inventories.	Free	http://geodata.grid.unep.ch/results.php
Air Pollution	Emissions of NOx	Emissions of Nox (total)	Tabular	CSV, HTML	Yes	Nation-state	Regional, national	2011	Various, ranges from 1990-2008	None	United Nations Environment Programme (UNEP)	Kenya, multiple	National Reports, United Nations Framework Convention on Climate Change (UNFCCC)	National figures only include data from UNFCCC Greenhouse Gas Inventory (GHG) Annex I Parties. These inventory data are provided in the national communications under the Convention by Annex I and non Annex I Parties, and in addition Annex I Parties submit annual national greenhouse gas inventories.	Web accessible	http://geodata.grid.unep.ch/results.php
Air Pollution	Emissions of particulates	Emissions of particulates (< 2.5 microns)	Tabular	CSV, HTML	Yes	Nation-state	Regional, national	2011	Various, ranges from 1990-2008	None	United Nations Environment Programme (UNEP)	Kenya, multiple	National Reports, United Nations Framework Convention on Climate Change (UNFCCC)	Freshwater Ecoregions of the World (FEOW) is a collaborative project led by WWF and TNC that provides the first global biogeographic regionalization of the Earth's freshwater biodiversity, and synthesizes biodiversity and threat data for the resulting eco	Web accessible	http://geodata.grid.unep.ch/results.php
Air Pollution	Emissions of SO2	Emissions of SO2 (total)	Tabular	CSV, HTML	Yes	Nation-state	Regional, national	2011	Various, ranges from 1990-2008	None	United Nations Environment Programme (UNEP)	Kenya, multiple	National Reports, United Nations Framework Convention on Climate Change (UNFCCC)	A global emissions source database called EDGAR has been developed jointly by TNO and RIVM to meet the urgent need of atmospheric chemistry and climate modelers and the need of policy-makers. The EDGAR database was to estimate the annual emissions of direct and indirect greenhouse gases (CO2, CH4, N2O; CO, NOx, non-methane VOC; SO2), including ozone-depleting compounds (halocarbons) for 1990 on a regional and grid basis.	Web accessible	http://geodata.grid.unep.ch/results.php
Air Pollution	Emissions of total GHG	Emissions of Total GHG (CO2. CH4, N2O, HFCs, PFCs, and SF6)	Tabular	CSV, HTML	yes	Nation-state	Regional, national	2011	Various, ranges from 1990-2008	None	United Nations Environment Programme (UNEP)	Kenya, multiple	National Reports, United Nations Framework Convention on Climate Change (UNFCCC)	National figures only include data from UNFCCC Greenhouse Gas Inventory (GHG) Annex I Parties. These inventory data are provided in the national communications under the Convention by Annex I and non Annex I Parties, and in addition Annex I Parties submit annual national greenhouse gas inventories.	Web accessible	http://geodata.grid.unep.ch/results.php
Air Pollution	Emissions of VOCs	Emissions of NMVOC	Tabular	CSV, HTML	Yes	Nation-state	Regional, national	2011	Various, ranges from 1990-2008	None	United Nations Environment Programme (UNEP)	Kenya, multiple	National Reports, United Nations Framework Convention on Climate Change (UNFCCC)	National figures only include data from UNFCCC Greenhouse Gas Inventory (GHG) Annex I Parties. These inventory data are provided in the national communications under the Convention by Annex I and non Annex I Parties, and in addition Annex I Parties submit annual national greenhouse gas inventories.	Web accessible	http://geodata.grid.unep.ch/results.php
Air Pollution	Total CH4 emissions	Emissions of CH4 - Total (Model Estimations, RIVM-MNP)	Tabular	CSV, HTML	Yes	Nation-state	Regional, national	2007	Various, ranges from 1990-2008	None	United Nations Environment Programme (UNEP)	Kenya, multiple	National Reports, United Nations Framework Convention on Climate Change (UNFCCC)	National figures only include data from UNFCCC Greenhouse Gas Inventory (GHG) Annex I Parties. These inventory data are provided in the national communications under the Convention by Annex I and non Annex I Parties, and in addition Annex I Parties submit annual national greenhouse gas inventories.	Web accessible	http://geodata.grid.unep.ch/results.php
Air Pollution	CO2 emissions	Emissions of CO2	Tabular	CSV, HTML	Yes	Nation-state	Regional, national	2007	Various, ranges from 1960 to 2007	None	United Nations Environment Programme (UNEP)	Kenya, multiple	National Reports, United Nations Framework Convention on Climate Change (UNFCCC)	National figures only include data from UNFCCC Greenhouse Gas Inventory (GHG) Annex I Parties. These inventory data are provided in the national communications under the Convention by Annex I and non Annex I Parties, and in addition Annex I Parties submit annual national greenhouse gas inventories.	Web accessible	http://geodata.grid.unep.ch/results.php
Biodiversity & Habitat	Biodiversity	Global 200 Ecoregion Database	Geospatial (vector)	ArcView GIS Shapefile	Yes	Not well defined	Global	2001	Not well defined	None	World Wildlife Fund	USA	World Wildlife Fund (WWF)	Maps the most biologically distinct terrestrial, freshwater, and marine ecoregions of the planet	Available online via registration. Access allowed for non-commercial scientific, conservation, and educational purposes.	http://www.worldwildlife.org/science/data/item1872.html

Category	Indicator	Name/Citation	Data type	File Type	Metadata Available	Resolution	Extent	Year Created	Data Years Available	Data Periodicity	Organization	Country of Origin	Source	Description	Availability	URL
Biodiversity & Habitat	Biodiversity	Terrestrial Ecoregions of the World	Geospatial (vector)	Not well defined	Yes	Not well defined	Global	2006	Not well defined	None	World Wildlife Fund	USA	World Wildlife Fund (WWF)	Maps 825 terrestrial ecoregions across the globe.	Available online via registration. Access allowed for non-commercial scientific, conservation, and educational purposes.	http://www.worldwildlife.org/science/data/item1872.html
Biodiversity & Habitat	Biodiversity	Terrestrial Ecoregions Base Global Dataset	Tabular	MS Excel	Yes	Not well defined	Global	2001	2001	None	World Wildlife Fund	USA	World Wildlife Fund (WWF)	This dataset was generated by intersecting multiple biological, environmental and population coverage's of the world and using, using spatial analyses and simple statistics. A separate report contains a detailed description of the processes involved in calculating the values in the BGDS, notes and explanations about some issues encountered during the analyses and a thorough description of each output variable. All the variables calculated were summarized for each of the 827 terrestrial ecoregions (Olson et al 2001), and were compiled into a spreadsheet for further use.	Free, available for valid scientific, conservation, and educational purposes	http://www.worldwildlife.org/science/data/item1872.html
Biodiversity & Habitat	Biodiversity hotspots	Hotspots Revisited	Geospatial (vector)	ArcView GIS Shapefile	Yes	0.000001 decimal degrees	Global	2005	2004	None	Conservation International	USA	Conservation International (CI), World Wildlife Fund (WWF), Wildlife Conservation Society (WCS)	The biodiversity hotspots are regions known to hold especially high numbers of species found nowhere else, yet their remaining habitat combined covers a little more than two percent of Earth's land surface. According to the criteria developed by Myers et al. (2000), a hotspot must meet two thresholds in order to qualify: 1) it must have at least 1,500 endemic, native vascular plant species, and 2) it must have already lost at least 70% of its primary, native vegetation. In the updated analysis, Mittermeier et al. (2004) recognize 34 hotspots which together hold 50% of the world's plant species and 42% of all terrestrial vertebrates as endemics. As evidence of their urgency for global conservation, hotspots also hold exceptionally high numbers of threatened vertebrates, including 50% of threatened mammals, 73% of threatened birds and 79% of threatened amphibians as endemics. There are an estimated two billion people living in the hotspots, with 300 million people within less than 10 km of existing protected areas.	Free	http://www.conservation.org/explore/priority_areas/hotspots/Pages/hotspots_main.aspx
Biodiversity & Habitat	Global protected areas	World Database on Protected Areas	Geospatial (vector)	ArcView GIS Shapefile	Not well defined	Not well defined	Global	2010	N/A	None	United Nations Environment Programme (UNEP) World Conservation Monitoring Center (WCMC)	United Kingdom	Various, primarily the UN Millennium Development Goals (MDGs) and Biodiversity Indicators Partnership	The World Database on Protected Areas (WDPA) is the only global database of both marine and terrestrial protected areas.	Web accessible map viewer.	http://www.protectedplanet.net/about
Biotechnology	Biotechnology	OECD Biotechnology Statistics	Text	PDF, HTML	Yes	Primarily OECD countries	Primarily OECD countries	2009	Various, ranges from 1980s to 2009	Various	Organization for Economic Co-Operation and Development (OECD)	Multiple	Surveys to study countries	The OECD Biotechnology Statistics – 2009 edition brings together the latest available economic and activity data on biotechnology and innovation, collected by OECD member and non-member countries. The report builds on the extensive work of the OECD and national experts to improve the comparability of biotechnology statistics. The 2009 edition contains government survey data for 22 OECD countries and additional data for four nonmember countries.	Free	http://www.oecd.org/dataoecd/4/23/42833898.pdf
Climate	Atmospheric and terrestrial data	The IPCC Data Distribution Centre	Tabular, Text	MS Excel, HTML, GRIB	Yes	Various, including 0.5°x0.5° and 10-arc min	Global, regional	2000	Various, ranges from 1901 to 1990	Various, down to monthly	Intergovernmental Panel on Climate Change	Switzerland, Various	Multiple sources	Provides access to baseline and scenario data for a range of non-climate conditions in the atmospheric, aquatic, and terrestrial environments.	Free	http://www.ipcc-data.org/ddc_envdata.html
Climate	Climate	WorldClim	Geospatial (raster)	ESRI grids	Yes	Various, from 30 arc-sec to 10 arc-min	Global	2005	Various, ranges from 1950 - 2000	Monthly	Consultative Group for International Agriculture Research (CGIAR) Consortium for Spatial Information (CSI)	USA	Museum of Vertebrate Zoology, UC Berkeley, International Center for Tropical Agriculture (CIAT), Rainforest Cooperative Research Center (CRC)	WorldClim is a set of global climate layers (climate grids) with a spatial resolution of a square kilometer.	This dataset is freely available for academic and other non-commercial use. Redistribution, or commercial use, is not allowed without prior permission.	http://worldclim.org/
Climate	Climate	National Climatic Data Center	Geospatial (raster)	ASCII	Yes	Various	Global, national	Continuous updating	Various, ranges from 1900 - present	Various, down to 15 minutes	National Oceanic and Atmospheric Administration (NOAA), Department of Commerce	USA	Multiple sources	We develop both national and global data sets that have been used by both government and the private sector to maximize the resource provided by our climate and minimize the risks of climate variability and weather extremes. The Center has a statutory mission to describe the climate of the United States and NCDC acts as the Nation's Scorekeeper regarding the trends and anomalies of weather and climate. NCDC's climate data have been used in a variety of applications including agriculture, air quality, construction, education, energy, engineering, forestry, health, insurance, landscape design, livestock management, manufacturing, recreation and tourism, retailing, transportation, and water resources management among other areas. Our data and products fulfill needs ranging from building codes to power plant and space shuttle design. Our Nation's climate data are critical to our modern lifestyles.	Free and fee-based.	http://www.ncdc.noaa.gov/oa/ncdc.html

Category	Indicator	Name/Citation	Data type	File Type	Metadata Available	Resolution	Extent	Year Created	Data Years Available	Data Periodicity	Organization	Country of Origin	Source	Description	Availability	URL
Climate	Climate	Climate Prediction Center (CPC) GIS Data	Geospatial (vector)	ArcView GIS Shapefile	Yes	Various	USA focus, some global	Various	Various	Various	National Oceanic and Atmospheric Administration (NOAA) / National Weather Service	USA	National Oceanic and Atmospheric Administration (NOAA) / National Weather Service	Weather-related data for soil moisture, evaporation, precipitation, runoff, temperature, seasonal drought outlooks, daily gridded precipitation analysis, sea surface temperature, and forecasts.	Free	http://www.cpc.ncep.noaa.gov/products/GIS/GIS_DATA/
Climate	Climate moisture indices	Climate moisture indices	Geospatial (raster), Image	ASCII, ArcInfo E00, JPEG	Yes	Not well defined	Global	1992	Not well defined	Annual	Water Systems Analysis Group, University of New Hampshire	USA	Multiple sources	Global field of long-term average annual climate moisture index (CMI, Willmott and Feddema, 1992) computed using the ratio of annual precipitation (P) to annual potential evapotranspiration.	Free. Data download / compatibility issues.	http://wwdrii.sr.unh.edu/download.html
Climate	Emissions of GHGs	Climate Analysis Indicators Tool	Tabular	MS Excel	Yes	Various, down to subnational scale	Global	2005, most recent	Various	Various	World Resources Institute	USA	Multiple sources	Provides a comprehensive and comparable database of greenhouse gas emissions data (including all major sources and sinks) and other climate-relevant indicators (socioeconomic and natural factors).	Free	http://cait.wri.org/cait.php
Climate	Mean sea level	Permanent Service for Mean Sea Level Data	Tabular	MS Excel	Yes	Global	Global	1933	Various, ranges from 1933 to present	Monthly, annual	Permanent Service for Mean Sea Level	UK	Permanent Service for Mean Sea Level	Global sea level data.	Free	http://www.psmsl.org/data/obtaining/
Climate	Vulnerability and adaption	Climate Analysis Indicators Tool - Vulnerability and Adaption	Tabular	MS Excel	Yes	Nation-state	Global	Various	Various	Irregular	World Resources Institute	USA	World Resources Institute (WRI)	Provides a set of carefully selected national-level indicators designed to encourage discussion on measuring vulnerability to climate change and adaptive capacity. Indicators focus on settlement & infrastructure; agricultural sensitivity; human health; environment, economic capacity; and human and institutional capacity.	Free	http://cait.wri.org/cait-va.php?page=intro
Climate, Conservation, Hazard, Health, Population, Poverty, Sustainability, Governance	Multiple types	World Data Center for Human Interactions in the Environment	Multiple types	Multiple types	Yes	Various	Global, regional, national	Various	Various	Various	Center for International Earth Science Information Network (CIESIN)	USA	Multiple sources	This portal, hosted by NASA's Socioeconomic Data and Applications Center (SEDAC), provides access to a wide range of global data, associated documentation, and visualization and analysis tools, and to the community of experts on global data.	Free	http://sedac.ciesin.columbia.edu/wdc/about.jsp
Climate, Elevation, Soil	Climate, elevation, soil	Databases and links to data on digital elevation, soil profiles, evapotranspiration, soil water deficit, climate projections, aridity	Geospatial (vector and Google Earth)	ArcView GIS Shapefile, KMZ	Yes	Various, mostly 30-arc sec	Global	Various	Various	Various	Consultative Group for International Agriculture Research (CGIAR) Consortium for Spatial Information (CSI)	Multiple countries	Multiple sources	Collection of data on population, poverty, climate, soils, crops, livestock, transportation, and biodiversity. Includes a link to other GeoSpatial Toolkits. Other themes include agriculture, atmosphere, disasters, environmental management, freshwater, human health, human settlements, land cover and land use, monitoring and environmental data, oceans and coastal areas, geology, geomorphology, hydrology, and terrestrial ecosystems.	Must submit request forms to document the intended use of the data.	http://www.cgiar-csi.org/data
Climate	Multiple types	NOAA Satellite and Information Service, National Oceanic and Atmospheric Administration	Multiple types	Multiple types	Yes	National, subnational	USA focus, links to global data	Various	Various	Various	National Oceanic and Atmospheric Administration (NOAA)	USA	Multiple sources	Includes climatic, land-based, air, marine, satellite, weather, paleoclimatology, and other data.	Free and fee-based.	http://www.nesdis.noaa.gov/
Conflict	Conflict events	Social Conflict in Africa Database (SCAD)	Tabular	MS Excel	Yes	National, subnational	Africa only	2009	1990-2009	Irregular	The Robert S Strauss Center, University of Texas Austin	USA	Associated Press & Agence France Presse news wires	Each event record contains information on start and end dates, the type of event, the actors and targets involved, the number of participants, the number of fatalities, use of government repression, event locations, and issues.	Free	http://ccaps.strausscenter.org/scad/pages/sp-about
Development	Agriculture & rural development, socio-economic, energy & mining, environment, health, infrastructure	World dataBank	Tabular	MS Excel	Yes	Various, down to subnational scale	Global, regional, national, subnational	Not well defined	Various, ranges from 1960 - 2009	Various	The World Bank	USA	Multiple sources	The World Bank provides tabular data on 420 indicators from the World Development Indicators (WDI) covering 209 countries from 1960 to 2009.	Free	http://data.worldbank.org/indicator
Economics	National accounts, monetary, people, government finance	IMF World Economic Outlook Database	Tabular	MS Excel	Yes	Nation-state	Global, regional, national	2010	2008-2015	Annual	International Monetary Fund	USA	Multiple sources	GDP, Purchasing Power Parity, inflation, unemployment, government expenditures & debt	Free	http://www.imf.org/external/pubs/ft/weo/2010/02/weodata/index.aspx
Energy	Energy use and production	BP Energy Outlook 2030	Tabular	MS Excel	Yes	Various, down to regional scale	Global, regional	2010	1990-2030	5 years	BP	UK	Multiple sources	5-year energy production and consumption projections for OECD regions.	Free	http://www.bp.com/sectiongenericarticle.do?categoryId=9035979&contentId=7066648
Energy	Energy use and resources	International Energy Statistics	Tabular	MS Excel	Yes	Various, down to nation-state scale	Global, regional, national	Various	Various	Various	U.S. Energy Information Agency	USA	Multiple sources	Energy data & projections on production, consumption, stocks, reserves, imports, exports, CO2 emissions, heat content, carbon intensity, conversions, population, and prices.	Free	http://www.eia.gov/cfapps/ipdbproject/IEDIndex3.cfm
Energy	Energy use, flows, and resources	International Energy Statistics	Tabular	MS Excel	Yes	Various, down to subnational scale	Global, regional, national, subnational	2010	1999-2010	Annual	International Energy Administration	France	Multiple sources	Energy data on energy production, trade, stocks, CO2 emissions. Open-source maps of some energy networks (European gas pipelines, etc)	Free	http://www.iea.org/stats/index.asp
Environment, Health, Economy, Location, Oceans, Farming, Elevation, Inland Waters	Multiple types	UNC GIS Data Finder	Geospatial, Tabular	Multiple types	Yes	Various	Various	2010	Various, ranges from 1990 to 2009	Various	University of North Carolina	USA	Multiple sources	Davis Library Research and Instructional Services actively collects spatial data resources.	Free	http://www.lib.unc.edu/reference/gis/datafinder/index.html
Environmental Burden of Disease	Communicable and noncommunicable diseases	Global Health Atlas	Tabular	MS Excel	Yes	Various, down to nation-state scale	Global, national	Various	Various	Various	World Health Organization	Switzerland	World Health Organization (WHO)	Global health information on communicable diseases, noncommunicable disease, human resources for health, and world health statistics.	Free	http://apps.who.int/globalatlas/DataQuery/default.asp
Environmental Burden of Disease	Environmental burden of disease (DALYs)	Global Health Observatory Database	Tabular	MS Excel	Yes	Various, down to nation-state scale	Global, national	2000	Various	Various	World Health Organization	Switzerland	World Health Organization (WHO)	Global health information on mortality, burden of disease, immunization, nutrition, epidemic prone diseases, and others. Risk factors include ambient air, indoor air, lead, water, sanitation, hygiene, climate change, occupational factors, nutrition, UV radiation, recreational water-quality, water-quality, community noise, and poverty.	Free	http://apps.who.int/ghodata/

Category	Indicator	Name/Citation	Data type	File Type	Metadata Available	Resolution	Extent	Year Created	Data Years Available	Data Periodicity	Organization	Country of Origin	Source	Description	Availability	URL
Environmental indicators	Agriculture, air and climate, forest, industry, inland waters, land, material resources, multilateral agreements, transport, waste, wildlife, environmental expenditure and taxes	OECD Biotechnology Statistics	Tabular	MS Excel	Yes	Primarily OECD countries	Primarily OECD countries	2008	Multiple	Various, mostly annual or 5 years	Organization for Economic Co-Operation and Development (OECD)	Multiple, based in Paris, France	Surveys to study countries	Environmental data on agriculture, air and climate, forest, industry, inland waters, land, material resources, multilateral agreements, transport, waste, wildlife, environmental expenditure and taxes	Free	http://www.oecd.org/document/0,3746,en_2649_201185_46462759_1_1_1_1,00.html
Environmental indicators	Air and climate, inland waters, land, forests, wildlife, waste, material resources, energy, agriculture, environmental expenditure and taxes	OECD Environmental Data Compendium	Tabular	MS Excel	Yes	Primarily OECD countries	Primarily OECD countries	2008	Various, ranges from 2004 to 2008	Various	Organization for Economic Co-Operation and Development (OECD)	Multiple, based in Paris, France	Surveys to study countries	As international concern about global environment and sustainable development becomes more pressing, government, business and the public all need reliable and harmonized data on the environment, including the ways in which it is affected by economic activity. The Compendium, revised regularly, presents data linking pollution and natural resources with activity in such economic sectors as energy, transport, industry and agriculture. It shows the state of air, inland waters, wildlife, etc., for OECD countries and describes selected Reponses by government and enterprises.	Free	http://www.oecd.org/document/49/0,3746,en_2649_34283_39011377_1_1_1_1,00.html
Environmental Performance Index	Environmental burden of disease, air pollution, water quality, biodiversity and habitat, forestry, fisheries, agriculture, climate change	Environmental Performance Index (EPI)	Tabular	MS Excel	Yes	Various, down to nation-state scale	Global, national	2006	2006, 2008, 2010	2 years	Yale Center for Law & Policy (Yale University) and Center for International Earth Science Information Network (CIESIN) (Columbia University)	USA	Yale Center for Law & Policy and Center for International Earth Science Information Network (CIESIN) (Columbia University)	Ranks countries based on environmental performance indicators to gauge at a national government scale of how close countries are to established environmental policy goals.	Free	http://epi.yale.edu/Files; http://epi.yale.edu:2008/Downloads
Environmental Sustainability Index	Air quality, biodiversity, land, water quality, air pollution, population, waste & consumption, water stress, natural resource management, environmental health, human sustenance, exposure to natural disasters, environmental governance, greenhouse gas emissions	Environmental Sustainability Index (ESI)	Tabular	MS Excel	Yes	Various, down to nation-state scale	Global, national	2005	2005	None	Yale Center for Environmental Law and Policy (YCELP), Center for International Earth Science Information Network (CIESIN) of Columbia University, World Economic Forum, and the Joint Research Centre of the European Commission	USA	Multiple sources	The 2005 Environmental Sustainability Index (ESI) benchmarks the ability of nations to protect the environment over the next several decades. It does so by integrating 76 data sets–tracking natural resource endowments, past and present pollution levels, environmental management efforts, and a society's capacity to improve its environmental performance into 21 indicators of environmental sustainability.	Free	http://sedac.ciesin.columbia.edu/es/esi/downloads.html#data
Environmental Vulnerability Index	Climate change, biodiversity, water, agriculture and fisheries, human health aspects, desertification, exposure to natural disasters	Environmental Vulnerability Index (EVI)	Tabular	MS Excel	Yes	Nation-scale	Global, national	2004	Not well defined	None	South Pacific Applied Geoscience Commission (SOPAC), the United Nations Environment Programme (UNEP)	Fiji	Multiple sources	To develop a robust operational global environmental vulnerability index which provides a relatively quick and inexpensive way of characterizing the vulnerability of natural systems (at the level of a region, state, province or island). The common basis on which the index is developed will allow users to monitor the condition of the environment and comparisons through time and among countries.	Free	http://sedac.ciesin.columbia.edu/es/compendium.html
Famine	Famine threat	Famine Early Warning Systems Network (FEWS NET)	Geospatial, Tabular	Not well defined	Yes	Various, down to subnational	Global, national, subnational	2011	Not well defined	Various, down to monthly	U.S. Agency for International Development (USAID)	USA	Multiple sources	Famine related data (livelihoods, food prices & production, market reviews) and satellite imagery (rainfall, vegetation, irrigation, water availability)	Data access issues.	http://www.fews.net/ml/en/product/Pages/default.aspx
Fisheries	Fishery production	Marine	Geospatial (vector)	ArcView GIS Shapefile	Yes	Nation-state	Regional, national	2009	1960-2007	Annual	United Nations Environment Programme (UNEP)	USA	Food and Agriculture Organization of the United Nations (FAO)	The annual series of aquaculture production for marine waters.	Free	http://geodata.grid.unep.ch/results.php
Fisheries	Fishery production	Inland waters	Geospatial (vector)	ArcView GIS Shapefile	Yes	Nation-state	Regional, national	2009	1960-2007	Various	United Nations Environment Programme (UNEP)	USA	Food and Agriculture Organization of the United Nations (FAO)	The annual series of aquaculture production for inland waters.	Free	http://geodata.grid.unep.ch/results.php
Fisheries	Fishery production	Total production	Geospatial (vector)	ArcView GIS Shapefile	Yes	Nation-state	Regional, national	2011	1960-2007	Various	United Nations Environment Programme (UNEP)	USA	Food and Agriculture Organization of the United Nations (FAO)	The annual series of total aquaculture production.	Free	http://geodata.grid.unep.ch/results.php

Category	Indicator	Name/Citation	Data type	File Type	Metadata Available	Resolution	Extent	Year Created	Data Years Available	Data Periodicity	Organization	Country of Origin	Source	Description	Availability	URL
Fisheries	Marine trophic index	Marine Trophic Index	Tabular	MS Excel	Yes	Nation-scale	Global, national	1999	1950-2006	Annual	Sea Around Us Project (Pew Charitable Trusts)	Canada	Sea Around Us Project (Pew Charitable Trusts)	Presents data on the impact to fisheries and the marine ecosystems of the world. Data includes information on the scale of countries' Exclusive Economic Zones, Large Marine Ecosystems, the High Seas, and other spatial scales. It emphasizes catch time series starting in 1950, and related series (e.g., catch value and catch by fishing gear or flag state), and fisheries-related information on every maritime country (e.g., government subsidies, marine protected areas, marine biodiversity).	Free	http://www.seaaroundus.org/
Fisheries	Number of threatened species	Fishes-Number of Threatened Species	Tabular	MS Excel	Yes	Not well defined	Global	2007	Various, ranges from 1996-2007	Not well defined	United Nations Environment Programme (UNEP)	Multiple	International Union for the Conservation of Nature (IUCN), Special Survical Commission (SSC)	Threatened species are those listed as Critically Endangered (CR), Endangered (EN) or Vulnerable (VU).	Free, but data access issues.	http://geodata.grid.unep.ch/results.php
Fisheries	Threatened species as a percent of species evaluated	Fishes-Threatened Species as Percent of Species Evaluated	Tabular	MS Excel	Yes	Not well defined	Global	2007	2007	Not well defined	United Nations Environment Programme (UNEP)	Multiple	International Union for the Conservation of Nature (IUCN), Special Survical Commission (SSC)	Threatened species are those listed as Critically Endangered (CR), Endangered (EN) or Vulnerable (VU).	Free, but data access issues.	http://geodata.grid.unep.ch/results.php
Forestry	Forests	Google Earth Engine API	Maps	KMZ	Yes	Various	Global	Various, data from the past 25 years	Not well defined	Various, down to daily	Google, Carnegie Institution for Science	USA	Multiple sources	The Google Earth Engine will allow researchers access to forest monitoring satellite data.	Not yet available.	http://earthengine.googlelabs.com/
Forestry	Forests	GLASlite	Image	Proprietary format	Various	Not well defined	Peru, Bolivia, Colombia, Ecuador, Brazil	2000	Not well defined	Not well defined	Carnegie Institution for Science	USA	Multiple sources	GLASlite uses remotely-sensed satellite data of the Andes Amazon region to identify forest cover, forest cover changes, and human-induced changes. Further analysis of output images can be done using ArcGIS.	Free, but requires software download.	http://claslite.stanford.edu/en/about/index.html
Forestry	Global forestry tables	Global Forest Resources Assessment 2010	Tabular	MS Excel	Yes	Nation-state	Global, national	2010	1990, 2000	10 years	Food and Agriculture Organization of the United Nations (FAO)	Italy	Food and Agriculture Organization of the United Nations (FAO)	Assesses forestry-related changes between 1990 and 2000. Country-level data.	Free	http://www.fao.org/forestry/fra/fra2010/en/
Governance	Governance	World Governance Indicators	Tabular	MS Excel	Yes	Nation-state	National	2010	1996-2009	Annual	The World Bank	US	Multiple sources	Ranks all countries on 6 dimensions of governance. Each dimension is supported by multiple data elements.	Free	http://info.worldbank.org/governance/wgi/index.asp
Health	Emerging infectious diseases (EIDs)	Global Trends in Emerging Infectious Diseases	Image	Not well defined	No	Not well defined	Global	2008	1940-2004	None	University of Georgia, Columbia University Earth Institute, Zoological Society of London (ZSL),	USA, England	University of Georgia, Columbia University Earth Institute, Zoological Society of London (ZSL),	A study appearing in the Feb. 21 issue of Nature presents the first scientific evidence that emerging diseases are on the rise and that zoonoses—diseases from wildlife—are the prime threat, due to encroachment of wild areas by human population growth and related impacts. A predictive model was created by correlating population data from the NASA Socioeconomic Data and Applications Center (SEDAC) operated by CIESIN with analysis of emerging diseases from 1940 to 2004. The result is a global map of emerging disease "hotspots" that shows a pattern of growing vulnerability to new diseases in rich as well as poor nations, with implications for further prediction and prevention.	Not well defined.	http://www.earth.columbia.edu/articles/view/2033
Land	Drought	National Integrated Drought Information System	Geospatial	Multiple types	Yes	Various	Global, United States	2007	Various	Various, down to 15 minutes	National Oceanic and Atmospheric Administration (NOAA)	USA	Multiple sources	The U.S. Drought Portal is part of the interactive system to: provide early warning about emerging and anticipated droughts; assimilate and quality control data about droughts and models; provide information about risk and impact of droughts to different agencies and stakeholders; provide information about past droughts for comparison and to understand current conditions; explain how to plan for and manage the impacts of droughts; and provide a forum for different stakeholders to discuss drought-related issues.	Free. Data download / compatibility issues.	http://www.drought.gov/portal/server.pt/community/drought_gov/202
Land	Global coastline	Global Coastline VI	Geospatial (vector)	ArcView GIS Shapefile	Yes	30 arc-sec	Global	2009	2009	None	iSciences	USA	U.S. Geological Survey (USGS) SRTM Water Body Data, National Oceanic and Atmospheric Adminstration (NOAA) World Vector Shoreline, and National Geospatial-Intelligence Agency (NGA) Global Shoreline	Global Coastline v1 is a global map at 1 arc-second of resolution (approximately 30 meters at the equator) defining which areas of the earth are land and which are ocean or sea. Global Coastline v1 was created by ISCIENCES, L.L.C., Ann Arbor, Michigan. The dataset was produced using USGS SRTM Water Body Data, with corrections; and NOAA World Vector Shoreline data for areas above 60 degrees north, outside of the SRTM coverage area. Global Coastline v1 provides a greater degree of accuracy within the SRTM coverage area. Future updates are planned to improve accuracy in non-SRTM covered areas. Global Coastline v1 dataset contains the same coastline definition as both a map mask (polygons) and as a map outline (line-based vector data layer). The image above shows the global vector at 30 arc-sec.	The free downloadable zip file (8.1 MB) contains a 1km (30 arc second) map. Commercial and research licenses are available for the 90 meter map (3 arc second) and 30 meter map (1 arc second).	http://geoserver.isciences.com:8080/geonetwork/srv/en/metadata.show?id=244&currTab=simple
Land	Land cover	UMD 1 km Global Land Cover	Geospatial (raster)	Not well defined	Yes	1 km x 1 km	Global	1994	Not well defined	Not well defined	University of Maryland, Laboratory for Global Remote Sensing Studies	USA	University of Maryland, Laboratory for Global Remote Sensing Studies	Classifies land cover by water, evergreen needleleaf forest, evergreen broadleaf forest, deciduous needleleaf forest, deciduous broadleaf forest, mixed forest, woodland, wooded grassland, closed shrubland, open shrubland, grassland, cropland, bare ground, and urban and built-up.	Data download issues.	http://www.geog.umd.edu/landcover/1km-map.html
Land	Land resource potential and constraints	Terrastat	Tabular	HTML	Yes	Various, down to nation-state scale	Regional, national	2000	Not well defined	Not well defined	Food and Agriculture Organization of the United Nations	Italy	Multiple sources	Land resource potential and constraints statistics at country and regional level.	Free	http://www.fao.org/nr/land/information-resources/terrastat/en/

Category	Indicator	Name/Citation	Data type	File Type	Metadata Available	Resolution	Extent	Year Created	Data Years Available	Data Periodicity	Organization	Country of Origin	Source	Description	Availability	URL
Land	Land use / land cover areas (LULC)	Earth Resources Observation and Science (EROS) Center	Text, Image	Multiple types	Yes	Various	Global, regional, subnational	Various	Various, as early at 1960	Various	U.S. Geological Survey	USA	Multiple sources	A portal for aerial photography, satellite images, elevation, land cover, and digitized maps.	Free and fee-based.	http://eros.usgs.gov/#/Find_Data/Products_and_Data_Available
Land	Natural disaster hotspots	Natural disaster hotspots	Geospatial (raster)	ASCII	Yes	Various, mostly 2.5-min grid	Global, regional	Various, mostly 2005	Various	Various, mostly annual	Center for Hazards & Risk Research at Columbia University	USA	Center for Hazards & Risk Research at Columbia University	Data files for natural disaster hotspots. These include hazard frequency and distribution, mortality risks and distribution, and economic loss risk deciles associated with cyclones, droughts, earthquakes, floods, landslides, and volcanoes.	Free	http://www.ldeo.columbia.edu/chrr/research/hotspots/coredata.html
Land	Soil and terrain	Global Soil and Terrain Database (WORLD_SOTER)	Geospatial (raster)	ArcInfo E00	Yes	1:25,000,000	Global	1988	Not well defined	None	Soil Resources Management and Conservation Service (AGLS) of the FAO Land and Water Development Division (AGL)	Italy	Food and Agriculture Organization of the United Nations (FAO), United Nations Educational, Scientific and Cultural Organization (UNESCO)	Data on the major soil groups.	Web accessible	http://www.fao.org/WAICENT/FAOINFO/SUSTDEV/EIdirect/gis/EIgis000.htm
Land Development	Wetlands	Marine Ecoregions of the World	Geospatial (vector)	ArcView GIS Shapefile	Yes	Not well defined	Global	2007	Not well defined	None	World Wildlife Fund	USA	World Wildlife Fund (WWF), The Nature Conservancy (TNC)	A biogeographic classification of the world's coasts and shelves.	Available online via registration. Access allowed for non-commercial scientific, conservation, and educational purposes.	http://www.worldwildlife.org/science/data/item1872.html
Land Use	Land use / land cover areas (LULC)	Global Map of Land Use/Land Cover Areas (GMLULCA)	Image	TIFF, JPEG	Not well defined	Not well defined	Global	2005-2006	Not well defined	Not well defined	International Water Management Institute (IWMI)	Sri Lanka	Multiple sources	This global land use/land cover (LULC) dataset depicts detailed classes of irrigated and rainfed agriculture. The most recent LULC products are from Boston University using MODIS (Friedl et al., 2002, Zhan et al., 2000). It is well known that no two global datasets match (DeFries and Townshend,1994) as a result of differences in methods, data sources, data types, data calibration, and data acquisition modes. The disaggregated 75-class IWMI GMLULCA can be used to derive classes that match the class names of USGS and MODIS LULC classes. The particular strength of IWMI's GMLULCA will be in its emphasis on irrigated and rainfed croplands and in establishing their sub-pixel areas (SPAs).	Free. Data download / compatibility issues.	http://www.iwmigiam.org/info/gmlulc/default.asp
Land use / land cover	Burnt land area	Global VGT Burnt Area Product 2000	Tabular	MS Excel	Yes	Nation-state	Global, national	2000	2000	Monthly (non-accumulative), Annual	Global Environment Monitoring Unit with the Joint Research Centre (JRC) in the European Commission (EC)	Italy	Multiple sources	Three tables are available. The data is derived from an analysis of remote sensed data. These files describe: (1) year 2000 monthly burned area (km2), number of scars (all clusters and individual pixels), average size of the scar (km2), % of total area of country burned (shown for the year 2000 synthesis only) estimates for all countries reporting burned areas; (2) monthly burned area (km2) estimates and monthly totals for all countries reporting burned areas; and (3) year 2000 burned area (km2), number of scars, average burn scar size (km2), and % of the category burned per country and broad vegetation type (derived from the University of Maryland global land cover product).	Free	http://bioval.jrc.ec.europa.eu/products/burnt_areas_gba2000/gba_statistics.php
Land, Forestry, Biodiversity & Habitat	Land changes in vegetation and environmental shocks	Global Land Cover Facility (GLCF) - Earth Science Data Interface (ESDI)	Multiple types	Multiple types	Yes	Various	Global, regional	Various	Various	Various	University of Maryland, Global Land Cover Facility	USA	Multiple sources	Links to original satellite imagery (ASTER, IKONOS, Landsat, MODIS, QuickBird, OrbView, and SRTM). Created products for land cover classification, tree cover continuous fields, burned areas in Russia, radiative fluxes, 2008 China quake/Hurricanes Katrina and Rita/2004 Tsunami, flood maps, vegetation, deforestation.	Free	http://www.landcover.org/index.shtml
Multiple	Agriculture (fertilizer, phosphorus, pesticides), cropland, aquaculture, GHGs, wood harvesting, deserts and arid land, water quality and use, population, protected areas, biodiversity	Rio to Joburg Dashboard of Sustainability	Model software	MS Excel	Yes	Nation-state	Global, national	2002	Multiple	Not well defined	Consultative Group on Sustainable Development Indices	Canada	Multiple sources	The "Dashboard of Sustainability" is a free, non-commercial software which presents complex relationships between economic, social and environmental issues in a highly communicative format aimed at decision-makers and citizens interested in Sustainable Development. It is also particularly recommended to students, university lecturers, researchers and indicator experts. For the 2002 World Summit on Sustainable Development (WSSD), the CGSDI published the "From Rio to Jo'burg" Dashboard, with over 60 indicators for more than 200 countries.	Contact owner	http://esl.jrc.it/envind/dashbrds.htm
Multiple	Agriculture, ecosystems, emissions, temperatures, land use, precipitation, soil	GRID-Europe	Geospatial	Multiple types	Yes	Various	Global, regional	Various	Various, ranges from 1974 to 1994	Various	United Nations Environment Programme (UNEP) Division of Early warning and Assessment (DEWA) / Global Resource Information Database (GRID) Europe	Multiple	Multiple sources	The GRID-Europe database is maintained for the purpose of assisting the international community and individual nations in making sound decisions related to resource management and environmental planning, and where applicable providing data for scientific studies. Within the overall GRID-network, GRID-Europe focuses on the acquisition or creation, documentation, archive and dissemination of Global and European digital georeferenced environmental data.	Free	http://www.grid.unep.ch/data/data.php

Category	Indicator	Name/Citation	Data type	File Type	Metadata Available	Resolution	Extent	Year Created	Data Years Available	Data Periodicity	Organization	Country of Origin	Source	Description	Availability	URL
Multiple	Air and climate, biodiversity, energy and minerals, forests, governance, inland water resources, land and agriculture, marine and coastal areas, natural disasters, and waste	UNSD Environmental Indicators	Tabular	MS Excel	Yes	Various, down to nation-state scale	Global, national	Not well defined	Various	Various	United Nations Statistics Division	USA	Multiple sources	UNSD Environmental Indicators disseminate global environment statistics on ten indicator themes compiled from a wide range of data sources. The themes and indicator tables were selected based on the current demands for international environmental statistics and the availability of internationally comparable data. Indicator tables, charts and maps with relatively good quality and coverage across countries, as well as links to other international sources, are provided under each theme.		http://unstats.un.org/unsd/environment/qindicators.htm
Multiple	Air temperature, precipitation, drought indices, paleoclimate	Climate Research Unit database	Geospatial (raster)	ASCII, ArcInfo E00	Yes	Various, including 5°x5° and 2.5°x3.75°	Global	2006	Various, ranges from 1961-2006	Monthly	University of East Anglia (UEA) Climatic Research Unit (CRU)	England	Multiple sources	Gridded datasets of surface temperature data over land areas and averages for the Northern and Southern Hemispheres and the Globe. Historical monthly precipitation data set for global land areas. Self-calibrating Palmer Drought Severity Index (scPDSI).	Free	http://www.cru.uea.ac.uk/cru/data/
Multiple	Atmosphere and climate, land use, water, biodiversity, desertification, albedo, soil types, natural disasters, and hydrology	TerraViva! GeoServer	Geospatial	Proprietary format	Yes	Various, mostly 2.5 min grid	Global	Not well defined	Various, ranges from 1950 to 2007	None	iSciences	USA	Multiple sources	This server hosts a number of interactive maps, GIS datasets, satellite imagery and related applications in their proprietary map file format "CTVM". Many of the files are contained in other references within this catalogue.	Free and fee-based.	http://geoserver.isciences.com:8080/geonetwork/srv/en/main.home
Multiple	Coastal and marine ecosystems, climate and atmosphere, biodiversity and protected areas, forest and grasslands, water resources and freshwater, population, energy and resources, agriculture and food, environmental governance	Earth Trends: The Environmental Information Portal	Tabular	CSV, HTML	Various	Various, down to subnational scale	Global, national, subnational	2001	Various	Various	World Resources Institute	USA	Multiple sources	Includes time-series information for over 500 variables, more than 2000 country profiles, as well as data tables, maps, and feature stories on a variety of environmental, social, and economic topics.	Free	http://earthtrends.wri.org/text/
Multiple	Crop production, food supply, food security, prices, agricultural resources, forestry, and fisheries	FAOSTAT	Tabular	MS Excel	Yes	Various, down to nation-state scale	Global, regional, national	Not well defined	Various	Various	Food and Agriculture Organization of the United Nations	Italy	Multiple sources	FAOSTAT provides time-series and cross-sectional data relating to food and agriculture for some 200 countries.	Free, requires registration.	http://faostat.fao.org/default.aspx
Multiple	Cyclones, droughts, earthquakes, fires, floods, landslides, tsunamis, volcanoes	UNEP Global Risk Data Platform	Geospatial (vector and raster), Tabular	ArcView GIS Shapefile, ASCII, MS Excel	Yes	Various	Global	Various	Various	Not well defined	United Nations Environment Programme (UNEP) Division of Early warning and Assessment (DEWA) / Global Resource Information Database (GRID)		Multiple sources	The PREVIEW Global Risk Data Platform is a multiple agencies effort to share spatial data information on global risk from natural hazards.	Free	http://preview.grid.unep.ch/index3.php?preview=data&lang=eng
Multiple	Disasters, health, energy, climate, water, weather, ecosystems, agriculture, and biodiversity	GEO Portal	Multiple types	Multiple types	Yes	Various	Global, regional, national	2002	Various	Various	Global Earth Observation System of Systems (GEOSS)	Switzerland	Multiple sources	The GEOportal provides an entry point to access Earth Observation information and services. It connects to a system of existing portals, addressing the GEO Societal Benefit Areas globally while also providing national and regional information to enhance understanding. Derived from ESA's Earth Observation Community Portal www.eoportal.org, this contribution to GEO will put the accent on remote sensing, geospatial-static and in-situ data, information and services. Maps, forecasts and other decision support tools, derived from satellite imagery and in situ observations, play an increasingly important role in the work of decision makers, sustainable development planners, and humanitarian and emergency managers in need of quick, reliable and up-to-date user-friendly cartographic products as a basis for planning and monitoring their activities.	Free	http://www.geoportal.org/web/guest/geo_home
Multiple	Energy, atmosphere, biodiversity, stratospheric ozone depletion, forests, urban areas, freshwater, coastal and marine areas, and international environmental initiatives	United Nations Environment Programme Geo Data Portal	Multiple types	Various, including MS Excel, ArcView GIS Shapefile, CVS, and HTML	Yes	Various, down to nation-state scale	Global, regional, national, subnational	2011	Various, primarily ranges from 1970s to present	Various	United Nations Environment Programme	Kenya, multiple	Multiple sources	Authoritative source for data sets used by UNEP and its partners. Its online database holds more than 450 different variables, as national, sub-regional, regional and global statistics or as geospatial data sets (maps), covering themes such as Freshwater, Population, Forests, Emissions, Climate, Disasters, Health and GDP. The data can be displayed and explored on-the-fly through maps, graphs, data tables, downloaded in various popular formats, or copied and pasted into word processors.	Free	http://geodata.grid.unep.ch/
Multiple	Environment, health, economy, education, people, poverty, MDGs	eAtlas of Global Development	Tabular	MS Excel	Yes	Nation-state	Global, national	2008	Various, ranges from 1970-2008	Annual	The World Bank	USA (headquarters)	Multiple sources	The World Bank eAtlas of Global Development maps and graphs more than 175 thematically organized indicators for over 200 countries, letting you visualize and compare progress on the most important development challenges facing our world.	Free	http://www.app.collinsindicate.com/worldbankatlas-global/en

Category	Indicator	Name/Citation	Data type	File Type	Metadata Available	Resolution	Extent	Year Created	Data Years Available	Data Periodicity	Organization	Country of Origin	Source	Description	Availability	URL
Multiple	Environmental stress (carbon emissions, rate of deforestation, people per square kilometer of arable land, and freshwater resources)	Country Indicators for Foreign Policy	Tabular	MS Excel	Yes	Various, down to nation-state scale	Global, regional, national	Various	Various, ranges from 1985 to 2000	Various	Carleton University	Canada	Multiple sources	The project represents an on-going effort to identify and assemble statistical information conveying the key features of the political, economic, social and cultural environments of countries around the world. The cross-national data generated through CIFP was intended to have a variety of applications in government departments, NGOs, and by users in the private sector. The data set provides at-a-glance global overviews, issue-based perspectives and country performance measures. Currently, the data set includes measures of domestic armed conflict, governance and political instability, militarization, religious and ethnic diversity, demographic stress, economic performance, human development, environmental stress, and international linkages.	Free. Data query limitations.	http://www.carleton.ca/cgi-bin/cifp/data.pl
Multiple	Footprints - ecological, population, cropland, grazing land, forest, fishing ground, carbon, built-up land,	Global Footprint Network (GFN) Ecological Footprint	Tabular	MS Excel	Yes	Nation-state	Global, national	2010	2007	Annual	Global Footprint Network	USA	Multiple sources	Global Footprint Network's 2010 Edition National Accounts provide comprehensive new data on humanity's pressure on resources, how that compares across 241 countries, territories, and regions, and how it relates to the planet's capacity to meet these demands. Released every year using internationally-approved methodology and data sources, the accounts seek to quantify the relationship between human affairs and the planet's finite resources. They are produced by Global Footprint Network on behalf of its partners and others in the world community who wish to use these results.	Free	http://www.footprintnetwork.org/en/index.php/GFN/page/ecological_footprint_atlas_2008/
Multiple	Irrigation and drainage development, geography and population, water resources, water use, conservation agriculture and water harvesting, environment and health	AQUASTAT Database Query	Tabular	MS Excel	Yes	Nation-state	Global, national	2006	Variable, from 1952 - 2010	5 years	Food and Agriculture Organization of the United Nations	Italy	Multiple sources	The online "Database Query". This database includes tabular data on these variables: geography and population; water resource; water use; irrigation and drainage development; conservation agriculture and water harvesting; and environment and health. Periods for this data range from 1952 to the present.	Free	http://www.fao.org/nr/water/aquastat/dbase/index.stm
Multiple	Irrigation, water, land use, drought, climate	IWMI RS/GIS Data Storehouse Pathway (DSP)	Geospatial (raster)	Multiple types (remote sensing)	Yes	Various	Global, regional, national, and river basin	2008	Various	Various	International Water Management Institute (IWMI)	Sri Lanka	Multiple sources	IWMI's centralized facility for all spatial data related activities. Provides access to water data, global irrigated area maps, river basins, and info/data on wetlands, droughts/monitoring, climate, freshwater ecosystems, poverty/water. Research projects include: global map of irrigated area (GMIA); drought monitoring system project (DMS); wetland mapping project (WMP); river basin irrigated area mapping projects; and water productivity studies project.	Data access issues.	http://www.iwmidsp.org/iwmi/info/main.asp
Multiple	Irrigation, water, land use, drought, climate	Water Data - Integrated Portal for IWMI & CPWF research data	Geospatial (raster)	Multiple types (remote sensing)	Yes	Various	Global, regional, national	Not well defined	Various	Various	International Water Management Institute (IWMI)	Sri Lanka	Multiple sources	WaterData is an integrated portal providing a one stop access to all data stored in IWMI's archive. Access to data is provided in compliance with copyrights, intellectual property rights and data agreements.	Data access issues.	http://waterdata.iwmi.org/
Multiple	Land diversity and quality, water, air quality, biodiversity, resource use	The Wellbeing of Nations: A Country-by-Country Index of Quality of Life and the Environment	Tabular	MS Excel	Yes	Nation-state	Global, national	2001	2001	Not well defined	Co-published by Canada's International Development Research Centre (IDRC) and Island Press, with the support of the World Conservation Union (IUCN), and the International Institute for Environment and Development (IIED)	Canada	Multiple sources	Presents a human and ecosystem well-being index. Environmental factors include land (diversity and quality), water (inland and sea), air (local air quality, global atmosphere), species and genes (wild and domesticated diversity), and resource use (energy, materials and resource sectors).	Book, also available in SEDAC Compendium.	http://sedac.ciesin.columbia.edu/es/compendium.html
Multiple	Population, GDP, cropland, agriculture, irrigated land, water resources, energy consumption	IPCC Socio-Economic Baseline Dataset	Tabular	MS Excel	Yes	Various, down to nation-state scale	Global, regional, national	1998	1993, 1990s	Irregular	Intergovernmental Panel on Climate Change	Switzerland, Various	Intergovernmental Panel on Climate Change (IPCC)	A set of country and regional-level indicators of socioeconomic and resource variables as estimated at the beginning of the 1990s. These data are reproduced from the IPCC report on The Regional Impacts of Climate Change: An Assessment of Vulnerability published in 1998 by Cambridge University Press. These data were collated from a variety of sources such as the World Bank, UNEP and FAO. Indicators include agriculture, biodiversity & habitat, economic conditions, energy, land cover, and population and human development	Free	http://sedac.ciesin.columbia.edu/ddc/baseline/index.html
Natural disasters	Geophysical, meteorological, hydrological, climatological, and biological disasters	Emergency Events Database (EM-DAT), the International Disaster Database	Tabular	MS Excel, HTML	Yes	Nation-state	Global, regional, national	1998	Various, ranges from 1900 to 2011	Various, mostly annual	Center for Research on Epidemiology of Disasters (CRED)	Belgium	Multiple sources	EM-DAT contains essential core data on the occurrence and effects of over 18,000 mass disasters in the world from 1900 to present. The database is compiled from various sources, including UN agencies, non-governmental organizations, insurance companies, research institutes and press agencies.	Free	http://www.emdat.be/database
Ocean and islands, water and sanitation, disaster	Multiple types	SOPAC Map Interface	Geospatial, Maps	Multiple types	Yes	Various	Pacific Islands	2010	Various	Various	Secretariat of the Pacific Community Applied Geoscience and Technology Division (SOPAC)	Fiji	Multiple sources	SOPAC's core work program involves the production of a lot of geographical information systems output; and these are mostly some combination of digital maps and geo-referenced datasets. GIS specialists within the work programs utilize a diverse set of toolsets to create, manage, analyze and display geospatial data on digital maps, which are acquired from diverse sources.	Access constraints	http://www.sopac.org/index.php/maps-and-spatial-data-repository

Category	Indicator	Name/Citation	Data type	File Type	Metadata Available	Resolution	Extent	Year Created	Data Years Available	Data Periodicity	Organization	Country of Origin	Source	Description	Availability	URL
Population	Population	Population (total, urban, and rural)	Geospatial (raster), Image	ASCII, ArcInfo E00, JPEG	Yes	30-min grid	Global	2000	1993, 1997	None	Water Systems Analysis Group, University of New Hampshire	USA	Multiple sources	Global population fields were constructed for the year using country-level demographic statistics from the World Resources Institute (WRI) Earth Trends database (http://earthtrends.wri.org/). The urban and rural population data sets were developed by spatially distributing the WRI 2000 country level population data among DMSP-OLS nighttime stable-lights imagery (Elvidge 1997a) and ESRI Digital Chart of the World populated places points (ESRI 1993). Country-level urban population was evenly distributed among the DMSP-OLS city lights data set at 1-kilometer grid cell resolution with detectable lights in at least 10 per cent of the cloud free observations (Elvidge 1997b). Where available, the spatial extents of major city locations with known demographic data (Tobler 1995) were superimposed in the DMSP-OLS city lights data set to enhance the accuracy of the urban population distribution. Rural population was spatially distributed equally among the DCW populated places points falling outside of the DMSP-OLS city lights extent. Total population is simply the sum of urban and rural population data sets.	Free. Data download / compatibility issues.	http://wwdrii.sr.unh.edu/download.html
Population	Population	LandScan™ 2009 Dataset	Geospatial (raster)	ESRI grid	Yes	30 arc-sec	Regional, national	2008, 1998	1990 and 2000 Census based	Annual	Oak Ridge National Laboratory, Geographic Information Science and Technology (East View Cartographic, Inc.)	USA	Oak Ridge National Laboratory, Geographic Information Science and Technology (East View Cartographic, Inc.)	The LandScan algorithm uses spatial data and imagery analysis technologies and a multi-variable dasymetric modeling approach to disaggregate census counts within an administrative boundary. Since no single population distribution model can account for the differences in spatial data availability, quality, scale, and accuracy as well as the differences in cultural settlement practices, LandScan population distribution models are tailored to match the data conditions and geographical nature of each individual country and region. The resolution is approximately 1 km. Represents an ambient population (average over 24 hours).	Free to federal government, for UN Humanitarian efforts, and educational research. Commercial, non-profit, and personal use license fees are determined on a case-by-case basis.	http://www.ornl.gov/sci/landscan/landscan_data_avail.shtml
Population	Population	Gridded Population of the World v3 (GPWv3)	Geospatial (raster)	ASCII, BIL, ArcInfo E00	Yes	Nation-state	Global, national	1990, 1995, 2000	1990, 1995, 2000, 2005, 2010, 2015	5 years	Socioeconomic Data and Applications Center (SEDAC), Center for International Earth Science Information Networks (CIESIN)	USA	Socioeconomic Data and Applications Center (SEDAC), Center for International Earth Science Information Networks (CIESIN)	GPWv3 demonstrates the spatial distribution of human populations across the globe. The purpose of the GPWv3 project is to provide a spatially disaggregated population layer that is compatible with datasets from social, economic, and earth science fields. The output is unique in that the distribution of human population is converted from national or subnational spatial units (usually administrative units) of varying resolutions, to a series of geo-referenced quadrilateral grids at a resolution of 2.5 arc minutes.	Free	http://sedac.ciesin.columbia.edu/gpw/global.jsp
Population	Population	Global Rural-Urban Mapping Project (GRUMP)	Tabular	MS Excel	Yes	Nation-state	Global, regional, national	1990, 1995, 2000	1990, 1995, 2000	5 years	Socioeconomic Data and Applications Center (SEDAC), Center for International Earth Science Information Networks (CIESIN)	USA	Socioeconomic Data and Applications Center (SEDAC), Center for International Earth Science Information Networks (CIESIN)	GRUMP provides a new suite of data products that add rural-urban specification to GPWv3. Allows a researcher to distinguish population spatially by urban and rural areas.	Free	http://sedac.ciesin.columbia.edu/gpw/
Population	Population	U.S. Census Bureau International Data Base (IDB)	Tabular	MS Excel	Yes	Nation-state	Global, national	2011, updated	Various, ranges from 1950-2050	Annual	U.S. Census Bureau	USA	U.S. Census Bureau	Global population trends, links to historical population estimates, population clocks, and estimates of population, births, and deaths occurring each year, day, hour, or second.	Free, but data is not aggregated.	http://www.census.gov/ipc/www/idb/index.php
Population	Population (rural)	GWSP Digital Water Atlas (2008). Map 43: Population (Rural) (V1.0). Available online at http://atlas.gwsp.org.	Geospatial (raster)	ASCII	Yes	0.5° x 0.5°	Global	2008	2000	None	Water Systems Analysis Group, University of New Hampshire	USA	Water Systems Analysis Group, University of New Hampshire	Rural population for year 2000 (total people per 0.5 degree grid cell). This map shows the distribution of rural population throughout the globe. This indicator provides a measure rural population and can be aggregated to basin, national, continental or global scales.	Data use limitations. Available online with registration.	http://wiki.gwsp.org/joom/index.php?option=com_content&task=blogcategory&id=34&Itemid=63
Population	Population (Rural)	UN World Urbanization Prospects	Tabular	MS Excel	Yes	Nation-state	Global, national	2009	1950-2050	5 years	United Nations, Department of Economic and Social Affairs	USA	United Nations, Department of Economic and Social Affairs	UN estimates and projections of the urban and rural populations of all countries in the world and of their major urban agglomerations	Free	http://esa.un.org/unpd/wup/index.htm
Population	Population (total)	GWSP Digital Water Atlas (2008). Map 44: Population (Total) (V1.0). Available online at http://atlas.gwsp.org.	Geospatial (raster)	ASCII	Yes	0.5° x 0.5°	Global	2008	2000	None	Water Systems Analysis Group, University of New Hampshire	USA	Water Systems Analysis Group, University of New Hampshire	Total population for year 2000 (total people per 0.5 degree grid cell). This map shows the distribution of total population throughout the globe. This indicator provides a measure of total population and can be aggregated to basin, national, continental or global scales.	Data use limitations. Available online with registration.	http://wiki.gwsp.org/joom/index.php?option=com_content&task=blogcategory&id=34&Itemid=63
Population	Population (Total)	UN World Urbanization Prospects	Tabular	MS Excel	Yes	Nation-state	Global, national	2009	1950-2050	5 years	United Nations, Department of Economic and Social Affairs	USA	United Nations, Department of Economic and Social Affairs	UN estimates and projections of the urban and rural populations of all countries in the world and of their major urban agglomerations	Free	http://esa.un.org/unpd/wup/index.htm
Population	Population (Urban growth rate)	UN World Urbanization Prospects	Tabular	MS Excel	Yes	Nation-state	Global, national	2009	1950-2050	5 years	United Nations, Department of Economic and Social Affairs	USA	United Nations, Department of Economic and Social Affairs	UN estimates and projections of the urban and rural populations of all countries in the world and of their major urban agglomerations	Free	http://esa.un.org/unpd/wup/index.htm
Population	Population (urban)	GWSP Digital Water Atlas (2008). Map 42: Population (Urban) (V1.0). Available online at http://atlas.gwsp.org.	Geospatial (raster)	ASCII	Yes	0.5° x 0.5°	Global	2008	2000	None	Water Systems Analysis Group, University of New Hampshire	USA	Water Systems Analysis Group, University of New Hampshire	Urban population for year 2000 (total people per 0.5 degree grid cell). This map shows the distribution of urban population throughout the globe. This indicator provides a measure urban population and can be aggregated to basin, national, continental or global scales.	Data use limitations. Available online with registration.	http://wiki.gwsp.org/joom/index.php?option=com_content&task=blogcategory&id=34&Itemid=63
Population	Population (Urban)	UN World Urbanization Prospects	Tabular	MS Excel	Yes	Nation-state	Global, national	2009	1950-2050	5 years	United Nations, Department of Economic and Social Affairs	USA	United Nations, Department of Economic and Social Affairs	UN estimates and projections of the urban and rural populations of all countries in the world and of their major urban agglomerations	Free	http://esa.un.org/unpd/wup/index.htm

Category	Indicator	Name/Citation	Data type	File Type	Metadata Available	Resolution	Extent	Year Created	Data Years Available	Data Periodicity	Organization	Country of Origin	Source	Description	Availability	URL
Population, Land Development	Human development footprint	Last of the Wild Data Global Human Footprint	Geospatial (raster)	ArcInfo Grids	Yes	Various, from 30 arc-sec to 1 min	Global, regional	2008	2005	None	Wildlife Conservation Society (WCS) and the Center for International Earth Science Information Network (CIESIN) Columbia University	USA	Wildlife Conservation Society (WCS) and the Center for International Earth Science Information Network (CIESIN) Columbia University	Human influence is a global driver of ecological processes on the planet, on par with climatic trends, geological forces, and astronomical variations. The Wildlife Conservation Society (WCS) and the Center for International Earth Science Information Network (CIESIN) at Columbia University have joined together to systematically map and measure the human influence on the Earth's land surface today. The Last of The Wild, Version Two depicts human influence on terrestrial ecosystems using data sets compiled on or around 2000. The Last of the Wild data collection includes the Human Influence Index (HII) grids, Human Footprint grids, and The Last of the Wild vector data.	Free	http://sedac.ciesin.columbia.edu/wildareas/downloads.jsp
Population, socio-economic, hazards, environmental indices, biodiversity, poverty, climate	Multiple types	Socioeconomic Data and Applications Center (SEDAC)	Multiple types	Multiple types	Yes	Various	Global, regional, national	Various	Various	Various	Center for International Earth Science Information Network (CIESIN), National Aeronautics and Space Administration (NASA)	USA	Multiple sources	SEDAC, the Socioeconomic Data and Applications Center, is one of the Distributed Active Archive Centers (DAACs) in the Earth Observing System Data and Information System (EOSDIS) of the U.S. National Aeronautics and Space Administration. SEDAC focuses on human interactions in the environment. Its mission is to develop and operate applications that support the integration of socioeconomic and Earth science data and to serve as an "Information Gateway" between the Earth and social sciences.	Free	http://sedac.ciesin.columbia.edu/
Water	Annual river discharge	GWSP Digital Water Atlas (2008). Map 39: Annual River Discharge (Dataset) (V1.0). Available online at http://atlas.gwsp.org.	Geospatial (raster)	Not well defined	Yes	0.5° x 0.5°	Global	2008	Not well defined	Annual	Water Systems Analysis Group, University of New Hampshire	USA	Water Systems Analysis Group, University of New Hampshire	Global annual river discharge for a 0.5 degree resolution digital river network (blended, km3/yr per grid cell). Blended river flow represents a composite of observed river discharge from the Global Runoff Data Centre and modeled river flow. River discharge represents the accumulation of surface waters into river conduits ultimately conveyed to the ocean or other receiving water body. Discharge volumes are correlated with upstream drainage area and average upstream runoff. Larger and wetter basins typically have higher discharge rates. Climate change associated with greenhouse gas warming could result in a potential acceleration of the hydrologic cycle leading to greater frequency and intensity of extreme events like floods and drought. Drainage basins located in transitional zones between humid and arid zones such as the Sahelian region of Africa may be most vulnerable to shifts in climate. Areas affected by seasonally precipitation patterns such as the monsoon region of India also represent climatically sensitive drainage basins. A monthly climatology of the dataset is also available.	Data use limitations. Available online with registration.	http://wiki.gwsp.org/joom/index.php?option=com_content&task=blogcategory&id=34&Itemid=63
Water	Blue water consumption on cropland	GWSP Digital Water Atlas (2008). Map 64: Blue Water Consumption on Cropland (Dataset) (V1.0). Available online at http://atlas.gwsp.org.	Geospatial (raster)	Not well defined	Yes	0.5° x 0.5°	Global	2008	1971-2000 average	Not well defined	Water Systems Analysis Group, University of New Hampshire	Germany	Potsdam Institute for Climate Impact Research	Blue water consumption on irrigated cropland (mm yr–1 per cropland area, 1971–2000 average). Blue water consumption in agriculture is restricted to irrigated areas. Highest consumption rates occur in warm regions. Blue water consumption rates occur in warm regions where green water (stemming directly from precipitation) is not sufficient to sustain optimal crop growth and where enough blue water is available to fulfill the resulting irrigation water requirements of the crops. Note that the values refer to cropland areas rather than to entire 0.5° grid cells, i.e. the influence of the fractional coverage of a grid cell with cropland is eliminated.	Free	http://wiki.gwsp.org/joom/index.php?option=com_content&task=blogcategory&id=34&Itemid=63
Water	Change in discharge due to deforestation	GWSP Digital Water Atlas (2008). Map 53: Change In Discharge due to Deforestation (Dataset) (V1.0). Available online at http://atlas.gwsp.org.	Geospatial (raster)	Not well defined	Yes	Not well defined	Global	2008	Not well defined	Not well defined	Water Systems Analysis Group, University of New Hampshire	USA	Water Systems Analysis Group, University of New Hampshire	Change in river flow (delta Q discharge, km3/yr) due to historical forest conversion to agriculture. This map shows gridded fields of changes in river discharge (delta Q) due to historical deforestation from Douglas et al. (2005). This historical scenario compared distributed river flow (Q) generated from pre-industrial land cover with river flow derived from contemporary land cover. One of the key factors in examining the effects of land use change, loss of biodiversity and hydrological function on human vulnerability is the recognition that populations affected by these changes are linked to disturbance through river networks.	Data use limitations. Available online with registration.	http://wiki.gwsp.org/joom/index.php?option=com_content&task=blogcategory&id=34&Itemid=63
Water	Change in discharge due to deforestation (relative)	GWSP Digital Water Atlas (2008). Map 54: Change In Discharge due to Deforestation (rel.) (Dataset) (V1.0). Available online at http://atlas.gwsp.org.	Geospatial (raster)	Not well defined	Yes	Not well defined	Global	2008	Not well defined	Not well defined	Water Systems Analysis Group, University of New Hampshire	USA	Water Systems Analysis Group, University of New Hampshire	This map shows gridded fields of the relative change in river discharge representing the ratio of the change in river discharge (?Q) due to historical deforestation divided by contemporary Q from Douglas et al. (2005). This historical scenario compared distributed river flow (Q) generated from pre-industrial land cover with river flow derived from contemporary land cover.	Data use limitations. Available online with registration.	http://wiki.gwsp.org/joom/index.php?option=com_content&task=blogcategory&id=34&Itemid=63
Water	Climate moisture index	GWSP Digital Water Atlas (2008). Map 40: Climate Moisture Index (Dataset) (V1.0). Available online at http://atlas.gwsp.org.	Geospatial (raster)	Not well defined	Yes	0.5° x 0.5°	Global	2008	Not well defined, but prior to 1992	Annual mean	Water Systems Analysis Group, University of New Hampshire	USA	Water Systems Analysis Group, University of New Hampshire	This map shows the Climate Moisture Index (CMI) indicator for the globe on a 0.5 X 0.5 degree global grid. The CMI illustrates the relationship between plant water demand and available precipitation. The CMI indicator ranges from –1 to +1, with wet climates showing positive CMI, and dry climates negative CMI. The CMI is an aggregate measure of potential water availability imposed solely by climate.	Data use limitations. Available online with registration.	http://wiki.gwsp.org/joom/index.php?option=com_content&task=blogcategory&id=34&Itemid=63

Category	Indicator	Name/Citation	Data type	File Type	Metadata Available	Resolution	Extent	Year Created	Data Years Available	Data Periodicity	Organization	Country of Origin	Source	Description	Availability	URL
Water	Climate, dams, river discharge, irrigation, land cover, population, projects, RBOs, runoff, tenders, treaties, water stress, news events	Transbourndary Freshwater Spatial Database	Web application	KMZ	Yes	Global watershed	Global	2011	Varies, from 1950 - 2011	Various	Institute for Water and Watersheds at Oregon State University	USA	Multiple sources	The Transboundary Freshwater Spatial Database is a compilation of the indicator variables used to analyze international river basins included in the Transboundary Freshwater Dispute Database. In this database, biophysical, socioeconomic, and geopolitical data relating to the world's international river basins are accessible and searchable through spatial and tabular formats. Spatial data, searchable at the international river basin and/or country scale, include climate, discharge, runoff, land cover, dam density, irrigation and population. Tabular data is also searchable by basin, including the International Freshwater Treaties Database, the International Water Events Database, and the Water Conflict and Cooperation Bibliography.	Thematic maps are not available for download.	http://www.transboundarywaters.orst.edu/database/transfreshspatdata.html
Water	Coefficient of variation for climate moisture index	GWSP Digital Water Atlas (2008). Map 65: Coefficient of Variation for Climate Moisture Index (Dataset) (V1.0). Available online at http://atlas.gwsp.org.	Geospatial (raster)	Not well defined	Yes	0.5° x 0.5°	Global	2008	Not well defined	Not well defined	Water Systems Analysis Group, University of New Hampshire	USA	Water Systems Analysis Group, University of New Hampshire	Coefficient of variation (CV) for long-term annual average climate moisture coefficient (CMI, unitless) computed from annual CMI fields. This map shows the Coefficient of Variation for Climate Moisture Index (CMI CV) indicator for the globe on a 0.5 X 0.5 degree global grid. The CMI CV illustrates time varying fluctuations bit intra- and inter-annual in the relationship between plant water demand and available precipitation. The Coefficient of Variation (CV) is a statistical measure of the potential seasonal and interannual fluctuations in water availability for regions. Increased climate variability indicates larger year-to-year fluctuations, and hence, less predictability in the climate. Increased CMI CV often occurs along the interfaces between humid and dry, for instance, in the Sahelian region of Africa and in the North American Great Plains. These are areas known for periodic, severe droughts and water scarcity.	Data use limitations. Available online with registration.	http://wiki.gwsp.org/joom/index.php?option=com_content&task=blogcategory&id=34&Itemid=63
Water	Coefficient of variation of monthly discharge	GWSP Digital Water Atlas (2008). Map 76: Coefficient of Variation of Monthly Discharge (Dataset) (V1.0). Available online at http://atlas.gwsp.org.	Geospatial (raster)	Not well defined	Yes	Not well defined	Global	2008	1993-2002	Not well defined	Water Systems Analysis Group, University of New Hampshire	USA	Complex Systems Research Center (CSRC), University of New Hampshire	Coefficient of variation (in percent) of modeled monthly discharge for the period 1993-2002 for major rivers. This map shows the coefficient of variation (CV) of monthly modeled discharge for the period 1993-2002 in percent and illustrates seasonal variations in discharge for major rivers. The Coefficient of Variation (CV) is a statistical measure of the potential seasonal and inter annual fluctuations in river discharge. High variability of discharge is observed in regions where the annual discharge regime is dominated by snow-melt, such as the high latitude regions in river basins draining into the Arctic Ocean, and in regions with a pronounced seasonal rainfall regime.	Free	http://wiki.gwsp.org/joom/index.php?option=com_content&task=blogcategory&id=34&Itemid=63
Water	Dams and capacity of artificial reservoirs	GWSP Digital Water Atlas (2008). Map 41: Dams and Capacity of Artificial Reservoirs (Dataset) (V1.0). Available online at http://atlas.gwsp.org.	Geospatial (vector)	ArcView GIS Shapefile	Yes	Not well defined	Global	2008	Not well defined	None	Water Systems Analysis Group, University of New Hampshire	USA	Water Systems Analysis Group, University of New Hampshire	This map shows the location of dams and reservoirs around the globe with the capacity of artificial reservoirs noted where available in the database. This map shows a global databank of 633 large impoundments from a series of world dam registers published by ICOLD and IWPDC (ICOLD, 1984; 1988; IWPDC, 1994; 1989).	Data use limitations. Available online with registration.	http://atlas.gwsp.org/index.php?option=com_content&task=view&id=99&Itemid=63
Water	Dams and reservoirs	Global Reservoir and Dam (GRanD) Database	Geospatial (vector)	ArcView GIS Shapefile	Yes	0.5° x 0.5°	Global	2008	Not well defined	None	Water Systems Analysis Group, University of New Hampshire	Canada	Mc Gill University	he Global Reservoir and Dam (GRanD) Database provides the location and main specifications of large global reservoirs and dams with a storage capacity of more than 0.1km³ both in point and polygon format. The current version 1.1 of GRanD contains 6,862 records of reservoirs with a cumulative storage capacity of 6,197km³ and their attribute data. The development of GRanD primarily aimed at compiling the available reservoir and dam information, correcting it through extensive cross-validation, error checking and identification of duplicate records, attribute conflicts or mismatches; and completing missing information from new sources or statistical approaches. The dams were geospatially referenced and assigned to polygons depicting reservoirs outlines at high spatial resolution.	Free	http://wiki.gwsp.org/joom/index.php?option=com_content&task=blogcategory&id=34&Itemid=63
Water	Domestic and industrial water use	Domestic and industrial water use, and their proportional use	Geospatial (raster), Image	ASCII, ArcInfo E00, JPEG	Yes	30-min grid	Global	2005	2000	None	Water Systems Analysis Group, University of New Hampshire	USA	Multiple sources	Gridded fields of domestic and industrial water use for 2000 (in millions of cubic meters per year per grid cell) at 30 minute (latitude by longitude) resolution. Sectoral water use statistics were from WRI (1998). Reporting years for each country varied so national statistics were normalized to year 2000 by applying usage trends recorded in corresponding regional time series (Shiklomanov, 1996). Domestic water demand was computed on a per capita basis for each country and distributed geographically with respect to the 1-km total population field. Industrial usage was applied in proportion to urban population. Grid-based aggregates at 30-min resolution were then determined for domestic plus industrial water demand.	Free. Data download / compatibility issues.	http://wwdrii.sr.unh.edu/download.html
Water	Domestic water use	GWSP Digital Water Atlas (2008). Map 46: Domestic Water Use (Dataset) (V1.0). Available online at http://atlas.gwsp.org.	Geospatial (raster)	Not well defined	Yes	0.5° x 0.5°	Global	2008	2000	None	Water Systems Analysis Group, University of New Hampshire	USA	Water Systems Analysis Group, University of New Hampshire	Global domestic water use for year 2000 (millions of m3/year per 0.5 degree grid cell). This map shows the distribution of contemporary domestic water use throughout the globe and illustrates the considerable demand for water in the highly populated and industrialized regions of the globe.	Data use limitations. Available online with registration.	http://wiki.gwsp.org/joom/index.php?option=com_content&task=blogcategory&id=34&Itemid=63

Category	Indicator	Name/Citation	Data type	File Type	Metadata Available	Resolution	Extent	Year Created	Data Years Available	Data Periodicity	Organization	Country of Origin	Source	Description	Availability	URL
Water	Drained agricultural areas	GWSP Digital Water Atlas (2008). Map 70: Drained Agricultural Areas (Dataset) (V1.0). Available online at http://atlas.gwsp.org.	Geospatial (raster)	Not well defined	Yes	5-arc min gird	Global	2008	Not well defined	Not well defined	Water Systems Analysis Group, University of New Hampshire	Germany	University of Frankfurt	The map shows the fraction of each 5 arc min by 5 arc min cell area that is equipped for improved drainage at the end of the 20th century. Artificial drainage decreases the average water content of the subsoil and accelerates the transport of water through the soil. Therefore, it influences nutrient transport by increasing leaching losses and by decreasing denitrification.	Free	http://wiki.gwsp.org/joom/index.php?option=com_content&task=blogcategory&id=34&Itemid=63
Water	Environmental water requirements	Environmental Water Requirements	Geospatial (raster)	Not well defined	Yes	Not well defined	Global	2008	Not well defined	None	Water Systems Analysis Group, University of New Hampshire	Sri Lanka	International Water Management Institute (IWMI)	This dataset presents a first attempt to estimate the volume of water required for the maintenance of freshwater-dependent ecosystems at the global scale. Fraction of mean annual flow requirement to maintain a river basin in some agreed ecological condition. The total environmental water requirement consists of ecologically relevant low-flow and high-flow components and depends on the objective of environmental water management. Both components are related to river flow variability and estimated by conceptual rules from discharge time series simulated by a global hydrology model.	Data use limitations. Available online with registration.	http://wiki.gwsp.org/joom/index.php?option=com_content&task=blogcategory&id=34&Itemid=63
Water	Environmental water stress indicator	Environmental Water Stress Indicator	Geospatial (raster)	Not well defined	Yes	Not well defined	Global	2008	Not well defined	None	Water Systems Analysis Group, University of New Hampshire	Sri Lanka	International Water Management Institute (IWMI)	The water stress indicator shows the proportion of the utilizable water in world river basins currently withdrawn for direct human use and where this use is in conflict with environmental water requirements.	Data use limitations. Available online with registration.	http://wiki.gwsp.org/joom/index.php?option=com_content&task=blogcategory&id=34&Itemid=63
Water	Flood risk distribution	GWSP Digital Water Atlas (2008). Map 78: Flood Risk Distribution (Dataset) (V1.0). Available online at http://atlas.gwsp.org.	Geospatial (raster)	Not well defined	Yes	2.5-min grid	Global	2008	1981-2000	None	Water Systems Analysis Group, University of New Hampshire	USA	Socioeconomic Data and Applications Center (SEDAC), Columbia University	Global Flood Mortality Risks and Distribution is a 2.5 by 2.5 minute grid of global flood mortality risks. In order to more accurately reflect the confidence associated with the data and the procedures, the potential mortality estimate range is classified into deciles, 10 classes of increasing hazard with an approximately equal number of grid cells per class, producing a relative estimate of flood-based mortality risks. Gridded Population of the World (GPW) Version 3.0 (beta) data provided a baseline population per grid cell from which to estimate potential mortality risks due to flood hazard. Mortality loss estimates per flood event are calculated using regional, hazard-specific mortality records of the Emergency Events Database (EM-DAT) that span the 20 years between 1981 and 2000. Data regarding the frequency and distribution of flood hazard are obtained from the Global Flood Hazard Frequency and Distribution dataset.	Free	http://wiki.gwsp.org/joom/index.php?option=com_content&task=blogcategory&id=34&Itemid=63
Water	Fractional green water consumption	GWSP Digital Water Atlas (2008). Map 62: Fractional Green Water Consumption (Dataset) (V1.0). Available online at http://atlas.gwsp.org.	Geospatial (raster)	Not well defined	Yes	Not well defined	Global	2008	1971-2000 average	Not well defined	Water Systems Analysis Group, University of New Hampshire	Germany	Potsdam Institute for Climate Impact Research	Green water fraction (%) of total crop water consumption, 1971–2000 average. Green water consumption dominates agricultural water consumption in most regions of the world.	Free	http://wiki.gwsp.org/joom/index.php?option=com_content&task=blogcategory&id=34&Itemid=63
Water	Freshwater ecoregions	GWSP Digital Water Atlas (2008). Map 69: Freshwater Ecoregions (Dataset) (V1.0). Available online at http://atlas.gwsp.org.	Geospatial (vector)	ArcView GIS Shapefile	Yes	Not well defined	Global	2008	Not well defined	None	Water Systems Analysis Group, University of New Hampshire	USA	The Nature Conservatory (TNC), World Wildlife Fund (WWF)	Freshwater Ecoregions of the World (FEOW) is a collaborative project led by WWF and TNC that provides the first global biogeographic regionalization of the Earth's freshwater biodiversity, and synthesizes biodiversity and threat data for the resulting ecoregions. A freshwater ecoregion is defined as a large area encompassing one or more freshwater systems that contains a distinct assemblage of natural freshwater communities and species. The freshwater species, dynamics, and environmental conditions within a given ecoregion are more similar to each other than to those of surrounding ecoregions and together form a conservation unit. The freshwater ecoregion map encompasses 426 units, whose boundaries generally - though not always - correspond with those of watersheds.	Free	http://wiki.gwsp.org/joom/index.php?option=com_content&task=blogcategory&id=34&Itemid=63
Water	Freshwater, drinking water, sanitation, water supply, cases of water-related illness, irrigated area, dams	The World's Water - Information on the World's Freshwater Resources	Tabular	MS Excel, PDF	Yes	Various, down to nation-state scale	Global, regional, national	1998-1999, 2002-2003, 2006-2007, 2008-2009	Various, ranges from 1970-2008	Various	Pacific Institute	USA	Multiple sources	Data on the world's freshwater. Includes data on consumption, access to sanitation and safe drinking water, pesticide occurrence, desalination plants, bottled water consumption, and others.	Free	http://www.worldwater.org/data.html
Water	Future change In discharge due to deforestation (rel.)	GWSP Digital Water Atlas (2008). Map 55: Future Change In Discharge due to Deforestation (rel.) (Dataset) (V1.0). Available online at http://atlas.gwsp.org.	Geospatial (raster)	Not well defined	Yes	Not well defined	Global	2008	N/A	Not well defined	Water Systems Analysis Group, University of New Hampshire	USA	Water Systems Analysis Group, University of New Hampshire	This map shows gridded fields of the relative change in river discharge representing the ratio of the change in river discharge (?Q) due to hypothetical future forest conversion to agriculture divided by contemporary Q from Douglas et al. (2005). This dataset compares river discharge (Q) generated from the contemporary land cover with river discharge generated from a hypothetical, 'worst-case' future deforestation scenario. The hypothetical future forest conversion scenario was designed as a 'worst-case' land cover change experiment that explored deforestation in the most vulnerable tracts of remaining forest and measure what effects this conversion could have on biodiversity, hydrological function and ultimately, on downstream human populations.	Data use limitations. Available online with registration.	http://wiki.gwsp.org/joom/index.php?option=com_content&task=blogcategory&id=34&Itemid=63

Category	Indicator	Name/Citation	Data type	File Type	Metadata Available	Resolution	Extent	Year Created	Data Years Available	Data Periodicity	Organization	Country of Origin	Source	Description	Availability	URL
Water	Future increase In discharge due to deforestation	GWSP Digital Water Atlas (2008). Map 56: Future Increase In Discharge due to Deforestation (Dataset) (V1.0). Available online at http://atlas.gwsp.org.	Geospatial (raster)	Not well defined	Yes	Not well defined	Global	2008	N/A	Not well defined	Water Systems Analysis Group, University of New Hampshire	USA	Water Systems Analysis Group, University of New Hampshire	Change in river flow (?Q discharge, km3/yr) due to a hypothetical, 'worst-case' future scenario for forest conversion to agriculture. This dataset compares river discharge (Q) generated from the contemporary land cover with river discharge generated from a hypothetical, 'worst-case' future deforestation scenario. The hypothetical future forest conversion scenario was designed as a 'worst case' land cover change experiment that explored deforestation in the most vulnerable tracts of remaining forest and measure what effects this conversion could have on biodiversity, hydrological function and ultimately, on downstream human populations. The conversion of the most vulnerable remaining forests in the hypothetical deforestation scenario would result in an additional loss of about 25% of contemporary tropical forests leaving just 9 million of the original 29 million km2 tropical forests intact.	Data use limitations. Available online with registration.	http://wiki.gwsp.org/joom/index.php?option=com_content&task=blogcategory&id=34&Itemid=63
Water	Global active river network	GWSP Digital Water Atlas (2008). Map 58: Global Active River Network (Dataset) (V1.0). Available online at http://atlas.gwsp.org.	Geospatial (raster)	Not well defined	Yes	30-min grid	Global	2008	Not well defined, but prior to 2000-2001	Monthly	Water Systems Analysis Group, University of New Hampshire	USA	Water Systems Analysis Group, University of New Hampshire	The global Simulated Topological Network (STN-30) represents rivers as a set of spatial and tabular data layers derived from a 30-minute flow-direction grid. The active river network represents only drainage flow paths that are actively flowing.	Data use limitations. Available online with registration.	http://wiki.gwsp.org/joom/index.php?option=com_content&task=blogcategory&id=34&Itemid=63
Water	Global drainage direction map	GWSP Digital Water Atlas (2008). Map 30: Global Drainage Direction Map (Dataset) (V1.0). Available online at http://atlas.gwsp.org.	Geospatial (raster)	Not well defined	Yes	30° x 30°	Global	2008	Not well defined	None	Water Systems Analysis Group, University of New Hampshire	Germany	Johann Wolfgang Goethe University, Frankfurt	This global drainage direction map DDM30 is a 30-min raster map of surface drainage directions which organizes the land area of the Earth into drainage basins and provides the river network topology. 66896 individual grid cells, covering the entire land surface of the globe (without Antarctica), are connected to each other by their respective drainage direction and are thus organized into drainage basins. Each cell can drain only into one of the eight neighboring cells.	Free	http://wiki.gwsp.org/joom/index.php?option=com_content&task=blogcategory&id=34&Itemid=63
Water	Global hydrological watersheds	HydroSHEDS	Geospatial (vector and raster)	ArcView GIS Shapefile, ESRI Grid, BIL	Yes	Various, from 3 arc-sec to 5 min	Global, regional	2006-2009	Various, ranges from 2006 to 2009	None	World Wildlife Fund	USA, Germany	World Wildlife Fund (WWF)	Stands for "**Hydro**logical data and maps based on **SH**uttle **E**levation **D**erivatives at multiple **S**cales." Allows scientists and managers to perform analyses ranging from basic watershed delineation to sophisticated flow modeling.	Available online. Access is allowed for valid scientific, conservation, and educational purposes.	http://hydrosheds.cr.usgs.gov/
Water	Global monthly precipitation measurements	Global Precipitation Climatology Project - Global analyses of monthly precipitation derived from satellite and surface measurements	Geospatial (raster)	ASCII	Not well defined	Various, primarily 2.5° x 2.5°	Global	Continuous updating	Various, 1979 - present	Monthly	National Oceanic and Atmospheric Administration (NOAA) / National Aeronautics and Space Administration (NASA)	USA	Multiple sources	The precipitation research groups in the Mesoscale Atmospheric Processes Branch (Code 613.1) have constructed a number of data sets containing estimates of precipitation which are available at this site. Some estimates are sufficiently well developed that other researchers can find the data and associated products useful. Potential users are urged to pay careful attention to the differences among the data sets and to check back for updates to the data sets. All local binary data sets are held in Silicon Graphics (big endian) format.	Data access issues.	http://precip.gsfc.nasa.gov/
Water	Global potential river network	GWSP Digital Water Atlas (2008). Map 59: Global Potential River Network (Dataset) (V1.0). Available online at http://atlas.gwsp.org.	Geospatial (vector)	ArcView GIS Shapefile	Yes	30-min grid	Global	2008	Not well defined	Not well defined	Water Systems Analysis Group, University of New Hampshire	USA	Water Systems Analysis Group, University of New Hampshire	The global Simulated Topological Network (STN-30) represents rivers as a set of spatial and tabular data layers derived from a 30-minute flow-direction grid. The potential river network represents all drainage flow paths whether they are actively flowing or dry.	Data use limitations. Available online with registration.	http://wiki.gwsp.org/joom/index.php?option=com_content&task=blogcategory&id=34&Itemid=63
Water	Green water consumption on cropland	GWSP Digital Water Atlas (2008). Map 63: Green Water Consumption on Cropland (Dataset) (V1.0). Available online at http://atlas.gwsp.org.	Geospatial (raster)	Not well defined	Yes	0.5° x 0.5°	Global	2008	1971-2000 average	Not well defined	Water Systems Analysis Group, University of New Hampshire	Germany	Potsdam Institute for Climate Impact Research	Green water consumption on rainfed and irrigated cropland (mm yr–1 per cropland area, 1971–2000 average). Green water is involved in agricultural water consumption around the world, including irrigated areas. The geographical differences in the absolute values reflect primarily the differences in the climatic conditions, with green water consumption being lowest in dry (or cool) regions (e.g. in southern Africa and central Asia) and highest particularly in the tropics but also in the northern temperate zone (Europe, eastern U.S.).	Free	http://wiki.gwsp.org/joom/index.php?option=com_content&task=blogcategory&id=34&Itemid=63
Water	Ground water	Global Ground Water Monitoring Network	Geospatial, Tabular	HTML, MS Excel	Yes	Not well defined	Global, regional, subnational	2003	Not well defined	Irregular	International Groundwater Resources Assessment Centre (IGRAC)	USA	Multiple sources	Global Groundwater Monitoring Group is establishing a sustainable Global Groundwater Monitoring Network (GGMN) aiming to use monitored data for a periodic assessment of the global groundwater resources. It should be noted that our intention is not to create a new, separate global network of monitoring wells. Likewise, no redesign of existing groundwater monitoring networks should be expected. The global monitoring network uses aggregated information from existing networks in order to represent a regional change of groundwater resources at the scale relevant for the global assessment. Data is available via the Ground Water Information System.	Login in required to access data.	http://www.igrac.net/publications/281
Water	Groundwater development	GWSP Digital Water Atlas (2008). Map 74: Groundwater Development (Dataset) (V1.0). Available online at http://atlas.gwsp.org.	Geospatial (vector)	Not well defined	Yes	Not well defined	Global	2008	Not well defined	None	Water Systems Analysis Group, University of New Hampshire	The Netherlands	International Groundwater Resources Assessment Centre (IGRAC)	This dataset shows the degree of groundwater development as a percentage of estimated recharge and the main groundwater use for global groundwater regions. Names for the regions are associated with the most pronounced geomorphologic features and relative geographical location on the particular continent.	Free	http://wiki.gwsp.org/joom/index.php?option=com_content&task=blogcategory&id=34&Itemid=63

Category	Indicator	Name/Citation	Data type	File Type	Metadata Available	Resolution	Extent	Year Created	Data Years Available	Data Periodicity	Organization	Country of Origin	Source	Description	Availability	URL
Water	Harmonisation of freshwater law	"GWSP Digital Water Atlas (2008). Map 22: Harmonisation of Freshwater Law (Dataset) (V1.0). Available online at http://atlas.gwsp.org.	Geospatial (vector)	Not well defined	Yes	Global river basins	Global	2008	Not well defined	None	Water Systems Analysis Group, University of New Hampshire	The Netherlands	Institute for Water Education, United Nations Educational, Scientific and Cultural Organization (UNESCO)	This map provides insights into a global harmonisation in the perspective of water law and water scarcity on a river basin scale. The aim of this map is to make a classification based of the following characteristics: 1) Does the regions authority ratified or supported the UN Convention on the Law of Non-Navigational Uses of International Water courses '97? 2) The amount of groundwater and freshwater treaties applicable per region. 3) Does the region suffer from water scarcity?	Free	http://wiki.gwsp.org/joom/index.php?option=com_content&task=blogcategory&id=34&Itemid=63
Water	Impervious surfaces	GWSP Digital Water Atlas (2008). Map 80: Impervious Surfaces (Dataset) (V1.0). Available online at http://atlas.gwsp.org.	Geospatial (raster)	Not well defined	Yes	30 m grid	Global	2008	2000-2001	Not well defined	Water Systems Analysis Group, University of New Hampshire	USA	National Geophysical Data Center (NGDC)	This dataset shows the spatial distribution and density of constructed impervious surface areas (ISA). The density of ISA for each grid cell is shown as a percentage of the total area.	Free	http://wiki.gwsp.org/joom/index.php?option=com_content&task=blogcategory&id=34&Itemid=63
Water	Industrial water use	GWSP Digital Water Atlas (2008). Map 45: Industrial Water Use (Dataset) (V1.0). Available online at http://atlas.gwsp.org.	Geospatial (raster)	Not well defined	Yes	0.5° x 0.5°	Global	2008	2000	None	Water Systems Analysis Group, University of New Hampshire	USA	Water Systems Analysis Group, University of New Hampshire	Global industrial water use for year 2000 (millions of m3/year per 0.5 degree grid cell). Distribution of contemporary industrial water use throughout the globe and illustrates the considerable demand for water in the highly populated and industrialized regions of the globe.	Data use limitations. Available online with registration.	http://wiki.gwsp.org/joom/index.php?option=com_content&task=blogcategory&id=34&Itemid=63
Water	International river basin management	Atlas of International Freshwater Agreements	Document, Image	PDF, HTML	Not well defined	Global watershed	Global	2002	Not well defined	Various	Institute for Water and Watersheds at Oregon State University, FAO, and UNEP	USA	Multiple sources	The Atlas of International Freshwater Agreements contains an historical overview of international river basin management; a detailed listing of more than 300 international freshwater agreements; and a collection of thematic maps related to the agreements, their content, and the river basins they represent. Published in cooperation with the United Nations Environment Programme (UNEP) and the Food and Agriculture Organization of the United Nations (FAO).	Free	http://www.transboundarywaters.orst.edu/publications/atlas/
Water	Introduction of national water law	GWSP Digital Water Atlas (2008). Map 21: Introduction of National Waterlaw (Dataset) (V1.0). Available online at http://atlas.gwsp.org.	Geospatial (vector)	ArcView GIS Shapefile	Yes	Nation-state	Global, national	2008	Various, from pre 1965 to 2002	Irregular	Water Systems Analysis Group, University of New Hampshire	The Netherlands	Institute for Water Education, United Nations Educational, Scientific and Cultural Organization (UNESCO)	This map visualizes the impact of several major international events regarding water governance on the introduction of national water law per country.	Free	http://wiki.gwsp.org/joom/index.php?option=com_content&task=blogcategory&id=34&Itemid=63
Water	Irrigated areas	Stefan Siebert, Petra Döll, Sebastian Feick, Jippe Hoogeveen and Karen Frenken (2007). Global Map of Irrigation Areas version 4.0.1. Johann Wolfgang Goethe University, Frankfurt am Main, Germany / Food and Agriculture Organization of the United Nations, R Source: GWSP Digital Water Atlas (2008). Map 31: Irrigated Areas (Dataset) (V1.0). Available online at http://atlas.gwsp.org.	Geospatial (raster)	Not well defined	Yes	5-min grid	Global	2007	2000	None	Water Systems Analysis Group, University of New Hampshire	Germany and Italy	Institute of Physical Geography, University of Frankfurt, and Land and Water Division, Food and Agriculture Organization, Rome	Area under irrigation around the year 2000, as percentage of surface area. The digital global map of irrigation areas was developed by combining sub-national irrigation statistics and geo-spatial information on the location and extent of irrigation schemes. The map shows the percentage of each 5 arc minute by 5 arc minute cell that was equipped for irrigation around the year 2000. Irrigation statistics for 26 909 sub-national units (e.g. districts, counties, provinces, governorates, river basins), from national census surveys and from reports available at FAO, World Bank and other international organizations, were used to develop the most recent map version 4.	Free	http://wiki.gwsp.org/joom/index.php?option=com_content&task=blogcategory&id=34&Itemid=63
Water	Lakes and wetlands	Global Lakes and Wetlands Database (GWLD)	Geospatial (vector)	Not well defined	Yes	Not well defined	Global	2004	2004	None	World Wildlife Fund	USA	World Wildlife Fund (WWF), University of Kansas' Center for Environmental Systems Research (CESR)	Maps the distribution of lakes and wetland types globally.	Available online via registration. Access allowed for non-commercial scientific, conservation, and educational purposes.	http://www.worldwildlife.org/science/data/item1872.html
Water	Likelihood of groundwater conflict 1	GWSP Digital Water Atlas (2008). Map 23: Likelihood of Groundwater Conflict 1 (Dataset) (V1.0). Available online at http://atlas.gwsp.org.	Geospatial (raster)	Not well defined	Yes	Nation-state	Global	2008	Not well defined	None	Water Systems Analysis Group, University of New Hampshire	The Netherlands	Institute for Water Education, United Nations Educational, Scientific and Cultural Organization (UNESCO)	This map shows groundwater conflict prone areas in relation to human access to improved water sources. Combining the percentage of the people with access to improved water sources and the groundwater 'treaty density' indicates those transboundary groundwater aquifers that are prone to conflict on the basis of the assumption that these factors are solely responsible for future groundwater conflicts.	Free	http://wiki.gwsp.org/joom/index.php?option=com_content&task=blogcategory&id=34&Itemid=63
Water	Likelihood of groundwater conflict 2	GWSP Digital Water Atlas (2008). Map 24: Likelihood of Groundwater Conflict 2 (Dataset) (V1.0). Available online at http://atlas.gwsp.org.	Geospatial (raster)	Not well defined	Yes	Nation-state	Global	2008	Not well defined	None	Water Systems Analysis Group, University of New Hampshire	The Netherlands	Institute for Water Education, United Nations Educational, Scientific and Cultural Organization (UNESCO)	Groundwater conflict prone areas in relation to the quantity of groundwater treaties signed per country. Combining the percentage of the people with access to improved water sources and the groundwater 'treaty density' indicates those transboundary groundwater aquifers that are prone to conflict on the basis of the assumption that these factors are solely responsible for future groundwater conflicts.	Free	http://wiki.gwsp.org/joom/index.php?option=com_content&task=blogcategory&id=34&Itemid=63
Water	Mean annual evapotranspiration 1950 - 2000	GWSP Digital Water Atlas (2008). Map 37: Mean Annual Evapotranspiration 1950 - 2000 (V1.0). Available online at http://atlas.gwsp.org.	Geospatial (raster)	Not well defined	Yes	0.5° x 0.5°	Global	2008	1950-2000 average	Annual mean	Water Systems Analysis Group, University of New Hampshire	USA	Water Systems Analysis Group, University of New Hampshire	This map shows average annual evapotranspiration for the globe on a 0.5 X 0.5 degree global grid. Evapotranspiration field represents a long term annual average (mm/yr) computed from monthly modeled evapotranspiration for years 1950-2000.	Data use limitations. Available online with registration.	http://wiki.gwsp.org/joom/index.php?option=com_content&task=blogcategory&id=34&Itemid=63

Category	Indicator	Name/Citation	Data type	File Type	Metadata Available	Resolution	Extent	Year Created	Data Years Available	Data Periodicity	Organization	Country of Origin	Source	Description	Availability	URL
Water	Mean annual precipitation 1950 - 2000	GWSP Digital Water Atlas (2008). Map 36: Mean Annual Precipitation 1950 - 2000 (V1.0). Available online at http://atlas.gwsp.org.	Geospatial (raster)	Not well defined	Yes	0.5° x 0.5°	Global	2008	1950-2000 average	Annual mean	Water Systems Analysis Group, University of New Hampshire	USA	Water Systems Analysis Group, University of New Hampshire	Precipitation field represents a long term annual average (mm/yr) computed from monthly modeled precipitation for years 1950-2000. This map illustrates the complexity of precipitation and atmospheric water cycle patterns across the globe.	Data use limitations. Available online with registration.	http://wiki.gwsp.org/joom/index.php?option=com_content&task=blogcategory&id=34&Itemid=63
Water	Mean annual surface runoff 1950 - 2000	GWSP Digital Water Atlas (2008). Map 38: Mean Annual Surface Runoff 1950 - 2000 (V1.0). Available online at http://atlas.gwsp.org.	Geospatial (raster)	Not well defined	Yes	0.5° x 0.5°	Global	2008	1950-2000 average	Annual mean	Water Systems Analysis Group, University of New Hampshire	USA	Water Systems Analysis Group, University of New Hampshire	This map shows average annual surface runoff for the globe on a 0.5 X 0.5 degree global grid. Runoff field represents a long term annual average runoff (mm/yr) computed from monthly modeled runoff for years 1950-2000. This map illustrates the complexity of runoff patterns across the globe.	Data use limitations. Available online with registration.	http://wiki.gwsp.org/joom/index.php?option=com_content&task=blogcategory&id=34&Itemid=63
Water	Nitrogen (dissolved inorganic flux)	GWSP Digital Water Atlas (2008). Map 50: Nitrogen (Dissolved Inorganic Flux) (V1.0). Available online at http://atlas.gwsp.org.	Geospatial (raster)	Not well defined	Yes	Not well defined	Global	2008	Not well defined, but prior to 2004	Annual	Water Systems Analysis Group, University of New Hampshire	USA	Water Systems Analysis Group, University of New Hampshire	Annual dissolved inorganic nitrogen flux at river mouth shown by basin (kgN/km2/yr per basin). This map shows dissolved inorganic nitrogen fluxes developed from a nitrogen transport model utilizing a global database of drainage basin characteristics and a comprehensive compendium of river chemistry observations.	Data use limitations. Available online with registration.	http://wiki.gwsp.org/joom/index.php?option=com_content&task=blogcategory&id=34&Itemid=63
Water	Nitrogen flux (total)	GWSP Digital Water Atlas (2008). Map 49: Nitrogen Flux (Total) (V1.0). Available online at http://atlas.gwsp.org.	Geospatial (raster)	Not well defined	Yes	Not well defined	Global	2004	Not well defined, but prior to 2004	Annual	Water Systems Analysis Group, University of New Hampshire	USA	Water Systems Analysis Group, University of New Hampshire	Annual nitrogen flux at river mouth shown by basin (kgN/km2/yr per basin). This map shows nitrogen fluxes developed from a nitrogen transport model utilizing a global database of drainage basin characteristics and a comprehensive compendium of river chemistry observations.	Data use limitations. Available online with registration.	http://wiki.gwsp.org/joom/index.php?option=com_content&task=blogcategory&id=34&Itemid=63
Water	Nitrogen load (instustrial fertilizer)	GWSP Digital Water Atlas (2008). Map 57: Nitrogen Load (Instustrial Fertilizer) (V1.0). Available online at http://atlas.gwsp.org.	Geospatial (raster)	Not well defined	Yes	0.5° x 0.5°	Global	2004	Not well defined, but prior to 2004	Not well defined	Water Systems Analysis Group, University of New Hampshire	USA	Water Systems Analysis Group, University of New Hampshire	Fertilizer loads (kgN/km2/yr per 0.5 degree grid cell) representing the amount of nitrogen applied to the land surface through industrial fertilizer use. Global, continental, regional, and coastline-specific estimates of fertilizer nitrogen loadings onto the continental land mass are derived by distributing country level industrial fertilizer use across mapped agricultural lands.	Data use limitations. Available online with registration.	http://wiki.gwsp.org/joom/index.php?option=com_content&task=blogcategory&id=34&Itemid=63
Water	Nitrogen load (mobilizable)	GWSP Digital Water Atlas (2008). Map 48: Nitrogen Load (Mobilizable) (V1.0). Available online at http://atlas.gwsp.org.	Geospatial (raster)	Not well defined	Yes	0.5° x 0.5°	Global	2004	Not well defined, but prior to 2004	Not well defined	Water Systems Analysis Group, University of New Hampshire	USA	Water Systems Analysis Group, University of New Hampshire	Mobilizable nitrogen loads (kgN/km2/yr per 0.5 degree grid cell) representing the amount of nitrogen on the land surface that is available to be transported to aquatic systems. Global, continental, regional, and coastline-specific estimates of nitrogen loadings onto the continental land mass are derived by applying a mass balance assessment of nitrogen loads to the landscape providing an accounting of nitrogen sources, uptake, transport and leakages to terrestrial and riverine systems.	Data use limitations. Available online with registration.	http://wiki.gwsp.org/joom/index.php?option=com_content&task=blogcategory&id=34&Itemid=63
Water	Reliable monthly water discharge	GWSP Digital Water Atlas (2008). Map 10: Reliable Monthly Water Discharge (V1.0). Available online at http://atlas.gwsp.org.	Geospatial (raster)	Not well defined	Yes	Not well defined	Global	2008	Various, ranges from 1961-1990	Monthly	Water Systems Analysis Group, University of New Hampshire	Germany	Center for Environmental Systems Research (CESR), Kassel	This is a statistical estimate of the minimum monthly flow which occurs over 90% of the months during the climate normal period (1961-90).	Data use limitations. Available online with registration.	http://wiki.gwsp.org/joom/index.php?option=com_content&task=blogcategory&id=34&Itemid=63
Water	Residence time change	GWSP Digital Water Atlas (2008). Map 75: Residence Time Change (V1.0). Available online at http://atlas.gwsp.org.	Geospatial (raster)	Not well defined	Yes	Not well defined	Global	2008	Not well defined	Not well defined	Water Systems Analysis Group, University of New Hampshire	USA	Complex Systems Research Center (CSRC), University of New Hampshire	This dataset shows the changes in the apparent water age in major rivers induced by the operation of large reservoirs. The change in the residence time (in days) were computed as the differences between modeled residence time under natural conditions and residence time taking into account the operation of reservoirs using a macroscale hydrological model. Vörösmarty et. al. (1997) introduced the concept of river water aging, related to residency time change of river flow through artificial impoundments, to illustrate the impact of the construction of reservoirs on discharge. It must not be confused with the true 'age' of water molecules that can be determined, for example, using tracer hydrological methods.	Free	http://wiki.gwsp.org/joom/index.php?option=com_content&task=blogcategory&id=34&Itemid=63
Water	River fragmentation by dams	Nilsson, C., Reidy, C.A., Dynesius, M., Revenga, C., 2005. Fragmentation and flow regulation of the world's large river systems. Science 308, 405–408. Source: GWSP Digital Water Atlas (2008). Map 25: River Fragmentation by Dams (V1.0). Available online at http://atlas.gwsp.org.	Geospatial (vector)	Not well defined	Yes	Not well defined	Global	2005	Not well defined, but prior to 2005	Not well defined	Water Systems Analysis Group, University of New Hampshire	Sweden	Umea University, Landscape Ecology Group	The map shows 292 of the world's largest river systems (LRSs), classified as either not affected, moderately affected or strongly affected by dams. White areas represent LRSs that did not meet the discharge criteria for inclusion in the study (VMAD ? 350 cms). Grey areas represent LRSs that might meet VMAD criteria for inclusion in the study but were data deficient.	Free	http://wiki.gwsp.org/joom/index.php?option=com_content&task=blogcategory&id=34&Itemid=63
Water	River fragmentation by dams	Nilsson, C., Reidy, C.A., Dynesius, M., Revenga, C., 2005. Fragmentation and flow regulation of the world's large river systems. Science 308, 405–408. Source: GWSP Digital Water Atlas (2008). Map 25: River Fragmentation by Dams (V1.0). Available online at http://atlas.gwsp.org.	Geospatial (vector)	Not well defined	Yes	Not well defined	Global	2005	1980s to early 1990s	Not well defined	Water Systems Analysis Group, University of New Hampshire	Sweden	Umea University, Landscape Ecology Group	Impact classifications, synthesized from channel fragmentation and flow regulation data, for 292 of the world's largest rivers. The map shows 292 of the world's largest river systems (LRSs), classified as either not affected, moderately affected or strongly affected by dams. White areas represent LRSs that did not meet the discharge criteria for inclusion in the study (VMAD ? 350 cms).	Free	http://wiki.gwsp.org/joom/index.php?option=com_content&task=blogcategory&id=34&Itemid=63

Category	Indicator	Name/Citation	Data type	File Type	Metadata Available	Resolution	Extent	Year Created	Data Years Available	Data Periodicity	Organization	Country of Origin	Source	Description	Availability	URL
Water	Rivers	Digitized river networks	Geospatial (raster), Image	ASCII, ArcInfo E00, JPEG	Yes	Various, from6-min grid to 30-min grid	Global, regional	2005	Not well defined	None	Water Systems Analysis Group, University of New Hampshire	USA	Multiple sources	The global Simulated Topological Network at 30-minute spatial resolution (STN--30) represents rivers as a set of spatial and tabular data layers derived from a 30-minute flow-direction grid. This dataset includes many different attributes (i.e., basin area, length, distance to river mouth, etc.). These datasets represents an update of Vörösmarty et al. (2000a, b) using methods developed in Fekete et al. (2001). See Additional Link for a description and download of attributes for the global potential network. The preview files show flow direction for potentially flowing river networks as well as the actively flowing networks (threshold > 3mm/yr upstream average runoff, Vörösmarty and Meybeck., 2004).	Free. Data download / compatibility issues.	http://wwdrii.sr.unh.edu/download.html
Water	Sediment trapping by large dams	GWSP Digital Water Atlas (2008). Map 51: Sediment Trapping by Large Dams (V1.0). Available online at http://atlas.gwsp.org.	Geospatial (raster)	Not well defined	Yes	Not well defined	Global	2008	Not well defined, but prior to 2005	Not well defined	Water Systems Analysis Group, University of New Hampshire	USA	Water Systems Analysis Group, University of New Hampshire	Global geography of basinwide trapping of suspended sediment flux by the large reservoirs. A total of 236 regulated basins with 633 large reservoirs (> 0.5 km3 maximum storage capacity), which collectively represent about 70% of registered impoundment storage volume was used to estimate basinwide relative loss of suspended sediment destined for the world's oceans.	Data use limitations. Available online with registration.	http://wiki.gwsp.org/joom/index.php?option=com_content&task=blogcategory&id=34&Itemid=63
Water	Short-term rainfall	STAR Satellite Rainfall estimates	Geospatial (raster)	ASCII	Unknown	4 m x 4 m	Global	Daily	Not clear	15 minutes over continental US, and 1- , 3-, 6- and 24-hours abroad	NOAA, Center for Satellite Applications and Research	USA	National Oceanic and Atmospheric Administration (NOAA), Center for Satellite Applications and Research	Rain gauges provide a direct measurement of rainfall; however, the spatial density of rain gauge networks (especially of gauges whose data are available in real time) is typically far too coarse to capture the spatial variability of rainfall at small scales. Radar provides an indirect measurement of rainfall, but only for regions within a few hundred km of a radar unit - and even less in mountainous regions due to blockage of the beam. Estimates of rainfall from satellite data are less direct and less accurate than either gauges or radar, but have the advantage of high spatial resolution (4 km) and complete coverage over oceans, mountainous regions, and sparsely populated areas where other sources of rainfall data are not available. Since flash flood events often originate with heavy rainfall in sparsely instrumented areas that goes undetected, satellite-derived rainfall can be a critical tool for identifying hazards from smaller-scale rainfall and flood events.	Data access issues.	http://www.star.nesdis.noaa.gov/smcd/emb/ff/index.php
Water	Virtual water flows between world regions	GWSP Digital Water Atlas (2008). Map 32: Virtual Water Flows between World-Regions (Dataset) (V1.0). Available online at http://atlas.gwsp.org.	Geospatial	Not well defined	Yes	Not well defined	Global, national	2008	1997-2001 average	Annual mean	Water Systems Analysis Group, University of New Hampshire	The Netherlands	University of Twente	Regional virtual-water balances and net interregional virtual-water flows over the period 1997-2001. The map shows the virtual-water balances for thirteen world regions. It also shows the largest net interregional virtual-water flows (>10 billion m3/yr). The virtual water balances and flows refer to trade in agricultural products only. The dataset was created within the context of the interdisciplinary research programme "Globalization of Water", carried out by the UNESCO-IHE Institute for Water Education and the University of Twente.	Free	http://wiki.gwsp.org/joom/index.php?option=com_content&task=blogcategory&id=34&Itemid=63
Water	Water availability	Water Conflict Chronology	Tabular	HTML	Yes	Various, down to subnational scale	Regional, national, subnational	Late 1980s	Various, ranges from antiquity - 2009	None	Pacific Institute	USA	Pacific Institute	Tracks and categorizes the historical connections between water resources, water systems, and international security and conflict. Issue categories include: Control of Water Resources; Military Tool, Political Tool; Terrorism; Military Target; and Development Disputes.	Free	http://www.worldwater.org/conflict/index.html
Water	Water balance (annual precipitation, evapotranspiration, runoff, and river discharge)	Gridded fields of major water balance components	Geospatial (raster), Image	ASCII, ArcInfo E00, JPEG	Yes	30-min grid	Global	2006	1950-2000	Annual	Water Systems Analysis Group, University of New Hampshire	USA	Multiple sources	Global gridded fields of long-term average (1950-2000) water balance components. Fields are input to (i.e.., precipitation) or output (I.e.., evapotranspiration, runoff, discharge) from the Water Balance Model (Vorosmarty et al., 1998) with improved interception function as recommended by Federer et al. (2003). Model climate inputs were from Mitchell et al. (2003). Monthly evapotranspiration computed using Shuttleworth and Wallace (1985) PET estimates (Vorosmarty et al, 1998) and limited by modeled soil moisture. River flow was computed as flow accumulated runoff along a 30-minute resolution digital river network (Fekete et al., 2001, Vörösmarty et al, 2000a,b). Blended river flow represents a composite of observed and modeled river flow. Land cover was represented by potential vegetation (Melillo et al., 1993) overlain with agricultural land cover (Ramankutty and Foley, 1999).	Free. Data download / compatibility issues.	http://wwdrii.sr.unh.edu/download.html
Water	Water conflict	Transboundary Freshwater Dispute Database (TFDD)	Geospatial	HTML	Not well defined	Global river basin	Global	Multiple	Multiple	None	Institute for Water and Watersheds, Program in Water Conflict Management and Transformation, Oregon State University	USA	Multiple sources	TFDD is used to aid in the assessment of the process of water conflict prevention and resolution, over the years we have developed this Transboundary Freshwater Dispute Database, a project of the Oregon State University Department of Geosciences, in collaboration with the Northwest Alliance for Computational Science and Engineering.	Free	http://www.transboundarywaters.orst.edu/database/
Water	Water consumption (total)	GWSP Digital Water Atlas (2008). Map 16: Water Consumption (total) (V1.0). Available online at http://atlas.gwsp.org.	Geospatial (raster)	Not well defined	Yes	0.5° x 0.5°	Global	2008	1995	None	Water Systems Analysis Group, University of New Hampshire	Germany	Center for Environmental Systems Research (CESR), Kassel	Annual total water consumption on a global grid estimated for 1995. Each year large volumes of water are consumed by the major water users which are households, factories, power plants and irrigation projects. This water will be supplied from the world's reservoirs, rivers, aquifers and other freshwater and saltwater sources. As the map shows, high water consumption can be found in areas with high population density.	Data use limitations. Available online with registration.	http://wiki.gwsp.org/joom/index.php?option=com_content&task=blogcategory&id=34&Itemid=63

Category	Indicator	Name/Citation	Data type	File Type	Metadata Available	Resolution	Extent	Year Created	Data Years Available	Data Periodicity	Organization	Country of Origin	Source	Description	Availability	URL
Water	Water consumption for agriculture	GWSP Digital Water Atlas (2008). Map 12: Water Consumption for Agriculture (V1.0). Available online at http://atlas.gwsp.org.	Geospatial (raster)	Not well defined	Yes	0.5° x 0.5°	Global	2008	Various, ranges from 1961-1990, 1995	Annual, none for livestock statistic (1995)	Water Systems Analysis Group, University of New Hampshire	Germany	Center for Environmental Systems Research (CESR), Kassel	Global water consumption for the agricultural sector. For irrigation the mean annual during the climate normal period (1961-1990) and for livestock the year 1995 are considered. Agricultural water consumption is the amount of water used to satisfy irrigation and livestock water demand. Thus the global distribution of areas with high agricultural water consumption are related to areas with intensive irrigation.	Data use limitations. Available online with registration.	http://wiki.gwsp.org/joom/index.php?option=com_content&task=blogcategory&id=34&Itemid=63
Water	Water consumption for domestic sector	GWSP Digital Water Atlas (2008). Map 13: Water Consumption for Domestic Sector (V1.0). Available online at http://atlas.gwsp.org.	Geospatial (raster)	Not well defined	Yes	0.5° x 0.5°	Global	2008	1995	None	Water Systems Analysis Group, University of New Hampshire	Germany	Center for Environmental Systems Research (CESR), Kassel	Annual water consumption for households and small businesses estimated for 1995. Water consumption is high in countries and areas with high population densities. Areas with less water consumption are located in countries and areas with low people density or areas with arid climate conditions were only a little water per capita is available.	Data use limitations. Available online with registration.	http://wiki.gwsp.org/joom/index.php?option=com_content&task=blogcategory&id=34&Itemid=63
Water	Water consumption for industry	GWSP Digital Water Atlas (2008). Map 14: Water Consumption for Industry (V1.0). Available online at http://atlas.gwsp.org.	Geospatial (raster)	Not well defined	Yes	0.5° x 0.5°	Global	2008	1995	None	Water Systems Analysis Group, University of New Hampshire	Germany	Center for Environmental Systems Research (CESR), Kassel	Annual water consumption for manufacturing and electricity industry estimated for 1995. The distribution of industrial water consumption is related to high industrialized areas and industry agglomerations. Primarily highest consumption is situated neighboring big cities with high population densities.	Data use limitations. Available online with registration.	http://wiki.gwsp.org/joom/index.php?option=com_content&task=blogcategory&id=34&Itemid=63
Water	Water consumption of power plants	GWSP Digital Water Atlas (2008). Map 1: Water Consumption of Power Plants (V1.0). Available online at http://atlas.gwsp.org.	Geospatial (raster)	Not well defined	Yes	Not well defined	Global	2008	Not well defined	Not well defined	Water Systems Analysis Group, University of New Hampshire	Germany	Center for Environmental Systems Research (CESR), Kassel	Location and water consumption of thermal power plants. Thermal Power plants deliver electricity for the population and its economic activity, they tend to be situated near population centers; because of their large water requirements, they also are usually sited near large waterways or other bodies of water.	Data use limitations. Available online with registration.	http://wiki.gwsp.org/joom/index.php?option=com_content&task=blogcategory&id=34&Itemid=63
Water	Water footprint per country	GWSP Digital Water Atlas (2008). Map 33: Water Footprint per Country (V1.0). Available online at http://atlas.gwsp.org.	Geospatial (vector)	ArcView GIS Shapefile	Yes	Nation-state	Global	2008	1997-2001 average	Annual	Water Systems Analysis Group, University of New Hampshire	The Netherlands	University of Twente	Average water footprint per capita per country for the period 1997-2001. Average water footprint per capita per country for the period 1997-2001. Green-colored countries have a water footprint per capita equal to or smaller than the global average; red-colored countries are beyond the global average.	Free	http://wiki.gwsp.org/joom/index.php?option=com_content&task=blogcategory&id=34&Itemid=63
Water	Water pollution (nitrogen loads, nitrogen flux, dissolved inorganic flux, water stress index, water reuse index).	Water pollution indicators	Geospatial (raster), Image	ASCII, ArcInfo E00, JPEG	Yes	Not well defined	Global	Not well defined	Various, up to 1998	Various, includes annual mean and monthly	Water Systems Analysis Group, University of New Hampshire	USA	Multiple sources	Gridded fields of nitrogen (N) loads and flux. Mobilizable N (N loads) represent the amount of N on the land surface that is available to be transported to aquatic systems. N fluxes represent the subsequent riverine nitrogen fluxes at the basin scale (Vörösmarty et al., 2000a,b; Fekete et al., 2001), for the contemporary setting (mid-1990's) in Green et al. (2004). Indicators include: mobilizable nitrogen loads (kg N/km2/yr per grid cell); total nitrogen flux (kg N/km2/yr per grid cell); basin-averaged dissolved inorganic nitrogen flux (kg N/km2/yr per grid cell); mean annual relative water stress index (unitless ratio per grid cell); monthly relative water stress index, month July (unitless ratio per grid cell); mean annual water reuse index (unitless ratio per grid cell); monthly water reuse index, month July (unitless ratio per grid cell).	Free. Data download / compatibility issues.	http://wwdrii.sr.unh.edu/download.html
Water	Water quality	GEMStat	Tabular	MS Excel	Yes	Location specific	Global, regional, national, subnational	Not well defined	Not well defined	Various	UN Global Environment Monitoring system (GEMS) Water Programme	Multiple countries	UN Global Environment Monitoring system (GEMS) Water Programme	GEMStat shares surface and ground water quality data sets collected from the GEMS/Water Global Network. Provides environmental water quality data and information collected at more than 3,000 stations. There are over 100 parameters.	Free	http://www.gemstat.org/
Water	Water resources	GWSP Digital Water Atlas (2008). Map 2: Water Resources (V1.0). Available online at http://atlas.gwsp.org.	Geospatial (raster)	Not well defined	Yes	Not well defined	Global	2008	Various, ranges from 1961-1990	Annual	Water Systems Analysis Group, University of New Hampshire	Germany	Center for Environmental Systems Research (CESR), Kassel	Discharge as runoff accumulated within drainage basins (accounting for evaporation from lakes and wetlands) for the "climate normal" period (1961-90). The Map depicts the average water resources available in drainage basins each year over the long-run. This map sharpens the contrast between adjacent water-rich and water-poor areas.	Data use limitations. Available online with registration.	http://wiki.gwsp.org/joom/index.php?option=com_content&task=blogcategory&id=34&Itemid=63
Water	Water resources	Water Resources Data Base (WRDB)	Geospatial (vector and raster)	Not well defined	Yes	Various, down to 1 m grid	Global, regional	Not well defined	Not well defined	Not well defined	U.S. Army Corps of Engineers, Army Geospatial Center	USA	Multiple sources	The Water Resources Data Base (WRDB) is produced and maintained by the Army Geospatial Center's (AGC's) Hydrologic Analysis Team. The WRDB provides information on quality, quantity, and availability of water resources in areas of the world of interest to the Department Of Defense (DoD). AGC's water resource layers are the primary data set populating the WRDB Geographic Information System (GIS); these are keyed to 1:250,000-scale Joint Operations Graphics maps and depict Existing Water Facilities, Surface Water supplies, and Ground Water resources. Coverage is global in extent but focused on arid and semi-arid regions of CENTCOM, EUCOM, and AFRICOM.	Access constraints	http://www.agc.army.mil/fact_sheet/wrdb.pdf
Water	Water scarcity index	Water Scarcity Index for Contemporary Conditions	Report	Image	No	Not well defined	Global	2008	Not well defined	None	Centre for the Study of Civil War (CSCW) at the International Peace Research Institute, Oslo (PRIO)	Oslo, Norway	Multiple sources	Building on propositions from the literature on environmental security, we have identified potential links between natural resource scarcity and violent conflict. Combining these propositions with environmental change scenarios from the Intergovernmental Panel on Climate Change (IPCC), we tested hypotheses about the expected relationships in a statistical model with global coverage. While previous studies have mostly focused on national-level aggregates, we used a new approach to assess the impact of environmental change on internal armed conflict by using geo-referenced (GIS) data and geographical, rather than political, units of analysis.	Free. Data download / compatibility issues.	http://www.wilsoncenter.org/topics/pubs/ECSPReport13_RaleighUrdal.pdf

Category	Indicator	Name/Citation	Data type	File Type	Metadata Available	Resolution	Extent	Year Created	Data Years Available	Data Periodicity	Organization	Country of Origin	Source	Description	Availability	URL
Water	Water stress	GWSP Digital Water Atlas (2008). Map 7: Water Stress (V1.0). Available online at http://atlas.gwsp.org.	Geospatial (raster)	Not well defined	Yes	Not well defined	Global	2008	Various, ranges from 1961-1990	Annual	Water Systems Analysis Group, University of New Hampshire	Germany	Center for Environmental Systems Research (CESR), Kassel	Withdrawals-to-availability ratio as conventional measure of water stress. The data is representing an output of the Water GAP model version 2.1D. This map is based on estimated water withdrawals for 1995, and water availability during the "climate normal" period (1961-90).	Data use limitations. Available online with registration.	http://wiki.gwsp.org/joom/index.php?option=com_content&task=blogcategory&id=34&Itemid=63
Water	Water stress	African water stress study	Geospatial (raster), Image	ASCII, ArcInfo E00, JPEG	Yes	Not well defined	Africa	2005	Various, ranges from 1950 - 1995	Various, annual and monthly	Water Systems Analysis Group, University of New Hampshire	USA	Multiple sources	Outputs from a Water Balance and Transport Model (WBM/WTM) were used to determine the spatial distribution of renewable water supply, expressed as the sum of local runoff and river corridor discharge.	Free. Data download / compatibility issues.	http://wwdrii.sr.unh.edu/download.html
Water	Water supply and sanitation	JMP Data and Estimates	Tabular	MS Excel	Yes	Nation-scale	Global, national	1995, 2000, 2005, 2008	Various, ranges from 1990-2008	3-5 years	WHO/UNICEF Joint Monitoring Program for Water Supply and Sanitation	Switzerland	World Health Organization (WHO) / United Nations Children's Fund (UNICEF) Joint Monitoring Program for Water Supply and Sanitation	Data on access to drinking-water and basic sanitation. Parameters include population, water (improved, piped, other improved, unimproved), sanitation (improved, shared, open defecation, other unimproved, total unimproved), urban, and rural.	Free	http://www.wssinfo.org/data-estimates/introduction/
Water	Water withdrawals (total)	GWSP Digital Water Atlas (2008). Map 20: Water Withdrawals (total) (Dataset) (V1.0). Available online at http://atlas.gwsp.org.	Geospatial (raster)	Not well defined	Yes	0.5° x 0.5°	Global	2008	Various, ranges from 1961-1990, 1995	Annual, none for livestock statistic (1995)	Water Systems Analysis Group, University of New Hampshire	Germany	Center for Environmental Systems Research (CESR), Kassel	Annual total water withdrawals of the current situation. Water withdrawn for the water use sectors industry , domestic, livestock are estimated for 1995. For irrigation mean annual withdrawals for the climate normal period 1961-1990 are considered. Large volumes of water are withdrawn by the major water users which are households, factories, power plants and irrigation projects. This water will be supplied from the world's reservoirs, rivers, aquifers and other freshwater and saltwater sources. As can be seen on the map high amounts of water are withdrawn in Europe, India, Pakistan, eastern parts of China, Japan, the United States and in countries of Latin America, like Mexico, Brazil and Argentina. Of course high water withdrawal occurs in densely populated and high industrialized areas. Large volume of water is used in many different ways, for example in private households for cooking, watering gardens, washing cars and so on. Industrial usage is once for cooling during manufacturing processes otherwise as a substance of content for industrial goods. In addition power plants have high water demand for reactor cooling. Irrigation is the dominating water use sector in rural areas with large irrigation	Data use limitations. Available online with registration.	http://wiki.gwsp.org/joom/index.php?option=com_content&task=blogcategory&id=34&Itemid=63
Water	Water withdrawals by basin	GWSP Digital Water Atlas (2008). Map 8: Water Withdrawals by Basin (V1.0). Available online at http://atlas.gwsp.org.	Geospatial (raster)	Not well defined	Yes	Not well defined	Global	2008	1995	None	Water Systems Analysis Group, University of New Hampshire	Germany	Center for Environmental Systems Research (CESR), Kassel	Annual total water withdrawals estimated for 1995 on a drainage basin basis. The units of the map [mm/a] indicate how much water is withdrawn per unit area of a drainage basin.	Data use limitations. Available online with registration.	http://wiki.gwsp.org/joom/index.php?option=com_content&task=blogcategory&id=34&Itemid=63
Water	Water withdrawals for agriculture	GWSP Digital Water Atlas (2008). Map 19: Water Withdrawals for Agriculture (V1.0). Available online at http://atlas.gwsp.org.	Geospatial (raster)	Not well defined	Yes	0.5° x 0.5°	Global	2008	Various, ranges from 1961-1990, 1995	Annual, none for livestock statistic (1995)	Water Systems Analysis Group, University of New Hampshire	Germany	Center for Environmental Systems Research (CESR), Kassel	For irrigation the mean annual water withdrawals during the climate normal period (1961-1990) and for livestock water withdrawals estimated for 1995 are considered. Most water used for irrigation is highly dominating agricultural water use. Thus most water is withdrawn in areas which are affected by intensive irrigation according to large irrigation projects.	Data use limitations. Available online with registration.	http://wiki.gwsp.org/joom/index.php?option=com_content&task=blogcategory&id=34&Itemid=63
Water	Water withdrawals for households	GWSP Digital Water Atlas (2008). Map 3: Water Withdrawals for Households (V1.0). Available online at http://atlas.gwsp.org.	Geospatial (raster)	Not well defined	Yes	Not well defined	Global	2008	1995	None	Water Systems Analysis Group, University of New Hampshire	Germany	Center for Environmental Systems Research (CESR), Kassel	Annual withdrawals for household and commercial uses estimated for 1995 on a drainage basin basis. The map shows that the needs for households are more spread out around the world than water uses for other purposes. This is expected since wherever people live, they require basic water services.	Data use limitations. Available online with registration.	http://wiki.gwsp.org/joom/index.php?option=com_content&task=blogcategory&id=34&Itemid=63
Water	Water withdrawals for industry	GWSP Digital Water Atlas (2008). Map 17: Water Withdrawals for Industry (V1.0). Available online at http://atlas.gwsp.org.	Geospatial (raster)	Not well defined	Yes	0.5° x 0.5°	Global	2008	1995	None	Water Systems Analysis Group, University of New Hampshire	Germany	Center for Environmental Systems Research (CESR), Kassel	Annual water withdrawals for manufacturing and electricity industry estimated for 1995. The distribution of industrial water withdrawal is related to high industrialized areas and industry agglomerations . Highest amount of water is withdrawn by big cities and their catchment areas. By country, the amount of water withdrawn for industry reflects the status of industrialization. The more developed countries are the more water is withdrawn from reservoirs and rivers.	Data use limitations. Available online with registration.	http://wiki.gwsp.org/joom/index.php?option=com_content&task=blogcategory&id=34&Itemid=63
Water	Water withdrawals for irrigation	GWSP Digital Water Atlas (2008). Map 4: Water Withdrawals for Irrigation (V1.0). Available online at http://atlas.gwsp.org.	Geospatial (raster)	Not well defined	Yes	Not well defined	Global	2008	Various, ranges from 1961-1990	Annual	Water Systems Analysis Group, University of New Hampshire	Germany	Center for Environmental Systems Research (CESR), Kassel	Theoretical water requirements for irrigated crops, taking into account the climate of the climate normal period (1961-90), and that usually only a small percentage of an area is equipped for irrigation. The map shows the water required for irrigation per unit area. To a certain extent the highest water withdrawals are located in areas with the highest density of irrigation projects.	Data use limitations. Available online with registration.	http://wiki.gwsp.org/joom/index.php?option=com_content&task=blogcategory&id=34&Itemid=63
Water	Water withdrawals for livestock	GWSP Digital Water Atlas (2008). Map 18: Water Withdrawals for Livestock (V1.0). Available online at http://atlas.gwsp.org.	Geospatial (raster)	Not well defined	Yes	0.5° x 0.5°	Global	2008	1995	None	Water Systems Analysis Group, University of New Hampshire	Germany	Center for Environmental Systems Research (CESR), Kassel	Amount of water that is withdrawn for livestock estimated for 1995. Accordingly to the development level of rural and agricultural regions water demand for livestock husbandry globally varies. Compared to other water usages, e.g. irrigation, water demand for livestock is much lower.	Data use limitations. Available online with registration.	http://wiki.gwsp.org/joom/index.php?option=com_content&task=blogcategory&id=34&Itemid=63
Water	Water withdrawals for manufacturing	GWSP Digital Water Atlas (2008). Map 5: Water Withdrawals for Manufacturing (Dataset) (V1.0). Available online at http://atlas.gwsp.org.	Geospatial (raster)	Not well defined	Yes	Not well defined	Global	2008	1995	Annual	Water Systems Analysis Group, University of New Hampshire	USA	Center for Environmental Systems Research (CESR), Kassel	Annual water withdrawals for the manufacturing industry estimated for 1995 on a drainage basin basis. This map shows gridded fields of changes in runoff due to historical deforestation and conversion to agriculture from Douglas et al. (2005). This historical scenario compared distributed runoff (RO) generated from pre-industrial land cover with runoff derived from contemporary land cover.	Data use limitations. Available online with registration.	http://wiki.gwsp.org/joom/index.php?option=com_content&task=blogcategory&id=34&Itemid=63

Appendix F
Remote Sensing

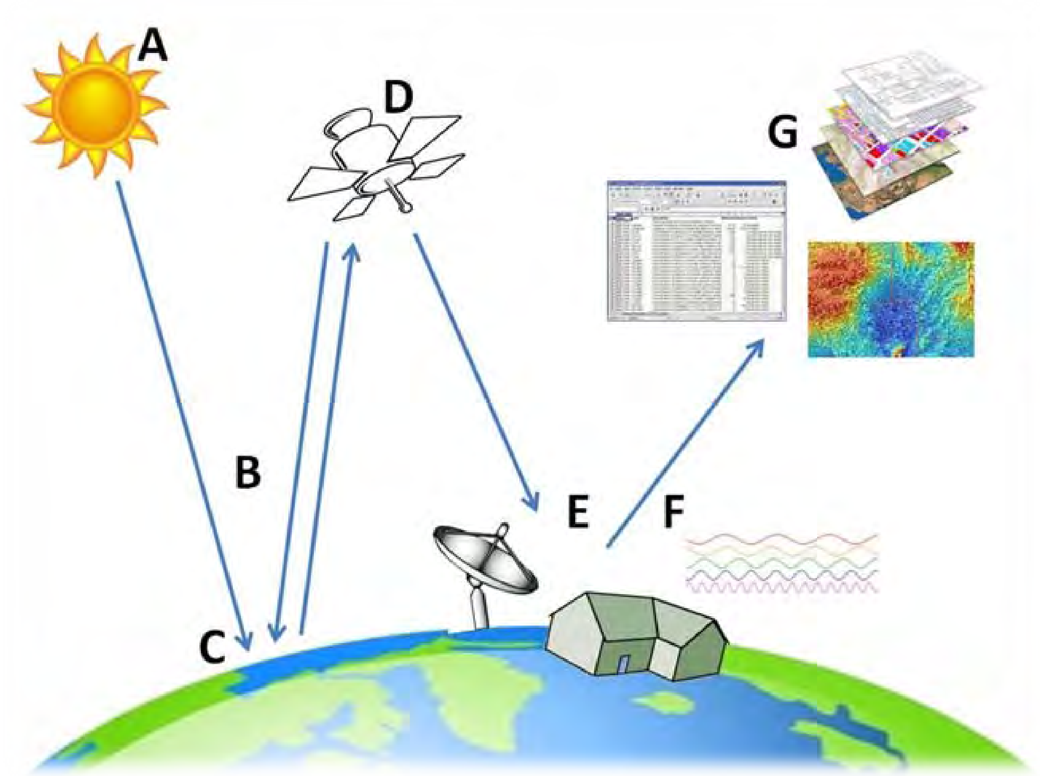
This appendix expands upon the discussion in Chapter 4 on the concept, processes, and applications of remote sensing. Further, it includes tables that describe most of the current domestic and international Earth observing satellite platforms, their sensors, and the derived data products that may be relevant to Army, other DoD, and US government users in efforts to develop geospatially explicit, conflict-instability-fragility analysis and early warning architectures, which can incorporate natural resource and environmental factors. Additional key resources are provided for users requiring greater in-depth information on specific concepts and components associated with remote sensing and how they can be applied to incorporate natural resource and environmental factors.

The focus of Earth system science is to observe and understand the Earth's complex interdependent processes as well as to predict global changes to these processes. The many components that together create the global environment include Earth surface and interior processes, water and energy cycling, atmospheric composition, carbon and nutrient cycling, and weather and climatic changes. A global approach is needed to adequately observe these dynamic systems, and remote sensing is an important tool for Earth system research, analysis, and decision making.

Remote sensing is the process of gathering spatially organized data from a remote location through sampling EM signals that emanate from a specific source target. Capturing and interpreting these signals can reveal information about objects and their features across different surfaces of the Earth.[1] Figure F-1 illustrates the required components of remote sensing and the basic process of receiving and interpreting EM signals, and processing them into useable data and analysis outputs.

[1] NASA, "The Concept of Remote Sensing; Sensors," http://rst.gsfc.nasa.gov/Intro/Part2_1.html.

Figure F-1. Remote Sensing Process Overview



A. Source of EM Energy. Remote sensing requires an energy source to emit EM energy, which will ultimately interact with the target and be intercepted by the sensor. Although active remote sensors do emit their own energy, the most common source of EM energy is that of the sun.

B. Interaction with the Atmosphere. Before and after the EM signal interacts with the target or sensed scene, it interacts with the atmosphere. Particles and gases within the atmosphere can often impact radiation via scattering (redirecting the energy from its original path) or absorption (molecules absorb energy at different wavelengths).

C. Interaction with the Target. EM energy from the sun that is not scattered or absorbed will reach the surface of the Earth and interact in one of three ways: absorption, transmission, or reflection. Remote sensing focuses predominately on intercepting energy reflected from a target. Two basic types of reflection can occur when EM energy reacts with a target: specular reflection, where all of the energy reflects off the surface of the target in a single direction, and diffuse reflection, where the surface of the target reflects the incoming radiation equally in all directions. Most surfaces on the Earth are neither fully spectral nor fully diffuse, but instead lie somewhere in between.

D. Interception by Sensor. Once the energy has been either reflected or scattered from the target, a remote sensor is required to capture and record the EM radiation. Remote sensors are either passive (detecting naturally available EM energy) or active (emitting their own EM energy, which is directed at the target). One obvious advantage of active sensors is the ability to collect measurements in the absence of sunlight, which is required to produce natural EM radiation.

E. Transmitting and Processing Signal. The EM energy measured by the sensor is transmitted to a station, where it is processed into an image.

F. Interpreting Signal. The processed image is analyzed and interpreted, and information about the target or sensed scene is extracted. In remote sensing, the signal is not usually of interest to users but rather the indirect information that can be derived through interpretation of the signal. For example, while a sensor does not directly measure the temperature in a specific region of the atmosphere, it can measure the EM energy emitted from a particular atmospheric compound found in that region, such as carbon dioxide, and determine the temperature through applying the measurement to known thermodynamic relationships.

G. Derived Data Products. Information extracted from signal interpretation is used to learn more about the target or sensed scene.

PLATFORMS/SATELLITES

Platforms are structures that house and transport remote sensing instruments. Typical platforms used outside of the atmosphere for Earth observation are satellites, spacecraft, and space stations, which all orbit the Earth. Platforms employed for remote sensing of other planets, moons, and asteroids or comets also include planetary orbiter satellites as well as flyby satellites, landers/rovers, and probes.[2] Within the Earth's atmosphere, typical remote sensing platforms include planes, helicopters, blimps, and balloons. In particular, satellite platforms have made significant contributions to global and regional Earth surveys conducted by commercial, military, governmental, and civil entities. Satellites, such as the Landsat series, have provided a nearly continuous global record of surface change, with data and images dating as far back as the 1970s.[3]

Several US government agencies and international organizations employ a variety of platforms to conduct remote sensing, many relying on orbiting satellites to cover regional or global targets. Other remote sensing platforms and sensors can be used as standalone information sources or to complement satellite data. Aerial photography taken from planes, helicopters, and unmanned aerial vehicles has been providing valuable visual and sensor information to the US military for decades. While not providing global coverage, these platforms can often generate finer-resolution data products for specific applications (in-theater tactical intelligence, border monitoring, etc.).

[2] NASA, "Technical and Historical Perspectives of Remote Sensing," 2011, http://rst.gsfc.nasa.gov/Front/tofc.html.

[3] USGS, "The Future of Landsat," 2010.

One advantage that satellite platforms have over lower-altitude airborne sensing platforms is that most airborne sensing missions are one-time operations. Satellites offer nearly continuous Earth monitoring, and though most satellites have a specific mission life, many have far outlived expectations to provide a decade or more of useable data.

Satellites are grouped by the orbits in which they are placed. Those with remote sensing missions are often placed in a geostationary or sun-synchronous orbit. Satellites in geostationary orbit are placed at a very high altitude (around 36,000 km) above the Earth's equator and follow a prograde orbit (orbit with the rotation of the Earth). Unless a geostationary satellite is capable of rotating or moving its sensors, its position and field of view are essentially fixed, allowing for continuous monitoring but limiting spatial resolution to 1–10 km.[4]

Other remote sensing satellite platforms are sun-synchronous, also referred to as polar-orbiting. Used more for observation at higher latitudes, satellites in this orbit are placed much closer to the surface of the Earth (700–1,000 km). These satellites travel at a steep inclination relative to the equator in a direction opposite the Earth's rotation.[5] These satellites are able to orbit the Earth in 100–120 minutes and can revisit a specific position after a certain period, usually no more than 2 weeks.[6]

SENSORS

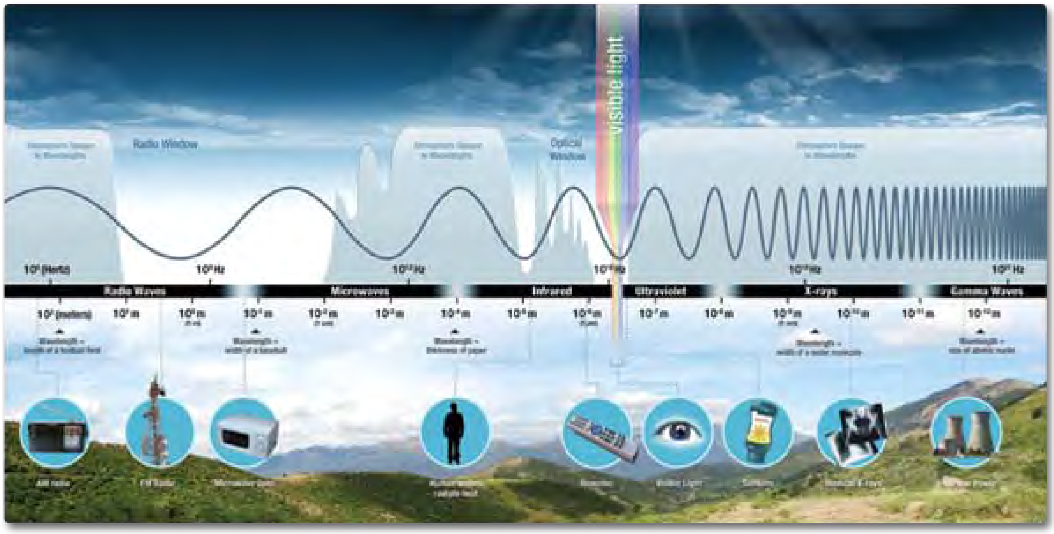
Platforms by themselves do not generate data but rather host the onboard sensors that do so. Sensors are defined by several characteristics: spectral properties, orbital altitude and path, swath width, and spatial and temporal resolution. A sensor's spectral properties consist of the placement and number of bands used by the sensor within the EM spectrum. This spectrum represents the range of all possible frequencies of EM radiation found in the universe. Sensors function by intercepting EM waves. Target objects and scenes selectively emit or absorb radiation frequencies across the entire EM spectrum (Figure F-2).

[4] CIESEN, "A CIESEIN Thematic Guide to Social Science Applications of Remote Sensing," October 2002.

[5] Ibid.

[6] Ibid.

Figure F-2. EM Spectrum



Source: NASA, Mission Science, Introduction to the Electromagnetic Spectrum, http://missionscience.nasa.gov/ems/01_intro.html.

In general, sensors fall into two basic spectral categories. Panchromatic sensors measure reflected energy within only one portion of the spectrum, most commonly in the visible or near-infrared range. Multispectral sensors can measure reflected energy in different, discrete portions of the spectrum, producing separate images referred to as bands or channels.[7]

The altitude and orbital path of a sensor depends on the placement and orbit of the sensor's platform. A sensor's swath width is the total area imaged by the sensor. For spaceborne sensors, swaths can vary in size between tens and hundreds of kilometers wide depending on the sensor's spatial resolution and altitude. Many sensors mounted on orbiting satellites provide an added advantage of producing a near complete coverage of the Earth's surface. Working with the rotation of the Earth, polar-orbiting satellites survey a new swath with each orbit, producing a near continuous, overlapping survey of the Earth's surface once the satellite returns to its initial position. Sensors mounted on geostationary platforms provide constant "eyes in the sky" for defined scenes.

Spatial Resolution

An additional defining characteristic of a sensor is its spatial resolution, which relates to the detail that a sensor can detect. The sensor resolution greatly influences the detail with which an image can be processed, analyzed, and viewed. Determining both the appropriate spatial resolution of a sensor as well as the appropriate platform to house the sensor is largely based on the type of data needed as well as the size of the target or sensed scene. For example, a

[7] Ibid.

high-resolution camera mounted on a low-flying aircraft is appropriate for capturing detailed images of streets and buildings, whereas a low-resolution sensor mounted on an orbiting satellite may be more appropriate for measuring ozone properties in the stratosphere. The spatial resolution of most remote sensing images is defined by the area represented by the smallest units of an image, or pixels. Pixels, also referred to as cells, are typically squared and organized into rows and columns to form a grid, with each cell containing a specific value that represents information about the area that the cell covers. If a sensor has a spatial resolution of 1 meter, then the each pixel within the grid covers an area on the ground of 1 meter by 1 meter. The finer or higher the resolution of a sensor is, the less total ground areas that can be sensed at one time. A sensor's spatial resolution can be as low as 0.6–10 meters, as is common in commercial high-resolution sensors on satellite platforms.[8]

Temporal Resolution

The concept of temporal resolution is also key attribute in remote sensing, particularly concerning satellite platforms and sensors. In this context, temporal resolution refers to the time required by a satellite platform to complete one entire orbit cycle. Also referred to as the revisit period, a satellite sensor often requires several days to re-sense the same areas at the same angle of viewing. Several factors can affect the absolute temporal resolution of a sensing satellite. For instance, some areas of the Earth are sensed more frequently due to swath overlapping that tends to occur from adjacent orbital paths. This overlap also increases as a satellite platform's altitude increases. Some satellites are also capable of adjusting positioning of their sensors to focus on a particular area with each orbital pass. Tables F-2 and F-3 both include information on the temporal resolution of the current US domestic and international Earth-sensing satellites.

DERIVED CAPABILITIES AND PRODUCTS

The EM signals captured by the remote sensors are not always used directly to obtain information about the sensed scene. However, through data processing, variables related to the sensed scene can be analyzed and extrapolated from the intercepted signals to create useable outputs and products. Obtaining this indirect information requires various levels of data processing. As part of its Earth Observing System (EOS) program, NASA defined four different levels of data processing to reflect the complexity and utility of the various stages of processing remote sensing derived data. Table F-1 defines these processing levels.

[8] NASA, "Remote Sensing Tutorial," Accessed at http://rst.gsfc.nasa.gov/.

Table F-1. Levels of Processing for Remote Sensing Data

Processing level	Definition	Example
Level 0	Reconstructed, unprocessed data at full resolution; all communications artifacts have been removed	Removing duplicated data, synchronizing data frames, radiometric corrections
Level 1	Level 0 data that has been time-referenced and annotated with ancillary information, including radiometric and geometric calibration coefficients, and geolocation information	Data enhancement, transformation
Level 2	Derived geophysical variables at the same resolution and location as the Level 1 data	Derived data, i.e. air temperature, soil moisture, ocean salinity
Level 3	Variables mapped on uniform space-time grids, usually with some completeness and consistency	Piecing together regional data, interpolating missing data points
Level 4	Model output or results from analyses of lower level data	Maps, aerial imagery, spreadsheets

Source: NASA, "Data Processing Levels," http://outreach.eos.nasa.gov/EOSDIS_CD-03/docs/proc_levels.htm.

The possible applications for remote sensing products are virtually endless. Earth observation sensors and systems are becoming critical for industry and governments to monitor, analyze, and adapt to changes in regional natural resources and the global environment. The potential impacts of environmental change in contributing to future fragility, instability, and conflict is increasingly becoming a focus in the national security community, and remote sensing systems can provide the accurate and timely data needed to respond to these growing issues.

The types of sensors used in Earth observation often dictate the potential outputs and capabilities. Several basic types of instruments are used in remote sensing, but each can be designed to fill more specific remote sensing needs. The following are instruments most commonly used in Earth observation and some of the broad or specific categories of environmental information that they can provide:

- RADAR—cloud properties, storm structure/intensity, global imaging, large-scale weather monitoring, and surveillance
- Altimeter—hydrological cycles; ocean circulation; and marine ice thickness
- LIDAR—topography and cloud aerosol profiles
- Radiometer—cloud emissivity, atmospheric particle size, deforestation, regional air quality, snow and ice extent, and plankton blooms

- Spectrometer—atmospheric composition, GHG distribution, sources, and sinks, distribution of ozone depleting substances, biogeochemical cycles in the atmosphere, and imaging
- Imager (MS or PAN)—human infrastructure, development patterns, land-use, vegetation health, rainfall intensity, cloud detection, migration patterns, and surveillance
- Sounder—atmospheric temperature and humidity profiles, energy flux, and aerosols distribution
- Magnetometer—Earth's geomagnetic field and sun-Earth interactions
- Scatterometer—ocean coverage and wind vector data.

Global Earth Observation System of Systems

Although remote sensing is an important component, it is by no means the sole component of Earth observation. Global Earth observation consists of many diverse systems and technologies that monitor, measure, understand, and forecast the Earth's processes. Typically, each of these systems functions in isolation, making the ever-increasing stream of environmental information difficult to disseminate to end-users and decision makers.

The amount of data needed for global observation of the Earth's systems and to answer important environmental questions is immense, particularly for the questions pertaining to climate change and its indirect roles in fragility, instability, and conflict. Compiling relevant images, measurements, and readings over long periods to produce useable end-products requires immense processing, integration, and visualization capabilities. Linking the many domestic and international producers of Earth observation data, furnishing the tools to analyze and understand the data, and providing decision support to the many end-user groups is the goal of the international Group on Earth Observations (GEO).

Built by the GEO, the Global Earth Observation System of Systems (GEOSS) is a global network of environmental data providers that offers users a single access point to an enormous amount of global data, imagery, analysis, and decision-support tools. GEOSS also links the existing and planned Earth observation systems and supports development of new systems to fill identified observational gaps. By promoting technical standards in data gathering and reporting, data from thousands of different instruments and observations systems can increasingly be combined into comprehensive and relevant datasets.

GEOSS consists of four main elements:

- The GEO Portal is the user interface through which the user can access the GEOSS and perform information searches.
- The GEOSS Clearinghouse directly connects GEOSS components and services, searching through information and distributing it to end users.
- Similar in function to a library catalog, the GEOSS Components and Services Registry contains essential details about the information contributions of each of the governments and organizations that participate.
- The GEOSS Standards and Interoperability Registry enables system integration among GEOSS contributors to better create a true system of systems process.[9]

Figure F-3. GEOSS "Societal Benefit Areas"

Image Source: Group on Earth Observations, 2011, www.earthobservations.org/geoss.shtml

Figure F-3 displays nine specific "societal benefit areas" identified to highlight content areas that can benefit most from GEOSS capabilities. Relevant past applications of GEOSS have included disaster management support in Central and

[9] International Group on Earth Observations, "The Global Earth Observation System of Systems (GEOSS)," Accessed at http://www.earthobservations.org/geoss.shtml.

South America as well as improved management of water resources in Asia, global fisheries, and even forecasting weather for the 2008 Olympics in Beijing.[10]

Construction of GEOSS began in 2005 on the basis of a 10-year implementation plan. Currently, GEOSS is cochaired by China, the European Commission, South Africa, and the United States. GEOSS comprises 86 member countries and 61 contributing organizations.[11]

In the European Union, a complementary initiative is taking a broad system-of-systems approach to geospatial data dissemination. The INSPIRE directive, launched in 2007, aims to create a European Spatial Data Infrastructure to allow for efficient sharing of environmental information across the public sector.[12] Of particular relevance to this report, the European initiative for Global Monitoring for Environment and Security (GMES) is a joint initiative between the European Commission and the European Space Agency aimed at improving access to quality environmental data for policymakers.[13]

REMOTE SENSING SATELLITE PLATFORMS

Tables F-2 and F-3 describe the majority of the current, unclassified US and international remote sensing satellites and, where available, details pertaining to the sensors and instruments installed on these platforms.

Table F-2. Remote Sensing Satellite Platforms in the United States

Series	Satellite	Launch date	Environmental sensor	Specifications (resolution, swath,	Temporal resolution	Applications
Afternoon Train (A-Train) Environmental-Observing Satellites (except EOS)	CloudSat	2006	CPR (Cloud Profiling Radar)	500 m vertical resolution	Daily	Cloud particles and the mass of water and ice within the clouds
	CALIPSO	2006	CALIOP (Cloud-Aerosol Lidar with Orthogonal Polarization)	30–60m vertical resolution, 333 m horizontal resolution	Daily	Vertical profiles of aerosols and clouds
			IIR (Imaging Infrared Radiometer)	1 km resolution, 64 x 64 km swath	Daily	Cirrus cloud emissivity and particle size
			WFC (Wide field camera)	125 m resolution, 61 km swath	Daily	Imagery

[10] Group on Earth Observation, "What is GEOSS?" Accessed at http://www.earthobservations.org/ geoss.shtml.

[11] Ibid.

[12] European Commission, "INSPIRE Directive," Accessed at http://inspire.jrc.ec.europa.eu/

[13] European Commission, "GMES- Observing Our Planet for a Safer World," Accessed at http://ec.europa.eu/enterprise/policies/space/gmes/.

Table F-2. Remote Sensing Satellite Platforms in the United States

Series	Satellite	Launch date	Environmental sensor	Specifications (resolution, swath,	Temporal resolution	Applications
	PARASOL	2004	POLDER (Polarization and Directionality of the Earth's Reflectance)	6 km resolution, 1,440 x 1,920 swath	Daily	Atmospheric composition, carbon cycle, ecosystems, biogeochemistry, climate variability and change, water and energy cycles
Future Satellites	OCO-2	2013	Three high resolution grating spectrometers	1.29 x 2.25 km resolution, 3 spectral channels	Daily	Global measurements of atmospheric carbon dioxide and characterization of regional-scale sources and sinks
U.S. Landsat/Earth Resources Technology Satellite (ERTS) Series	Landsat-7	1999	ETM (Enhanced Thematic Mapper)	30 m (visible, near and mid-IR), 15 m (panchromatic), 60 m (Thermal Infrared); 185 km swath	16 days	Changes in human infrastructure, Development patterns, Migration patterns, Agricultural variations, Urban/Rural interchange
Future Satellites	Landsat-8	2012	OLI (Operational Land Imager)	30 m resolution	16 days	Changes in human infrastructure, Development patterns, Migration patterns, Agricultural variations, Urban/Rural interchange, enhanced cloud detection
U.S. Commercial Environmental-Observing Satellites	IKONOS-2	1999	MMS (Multispectral) and PAN (Panchromatic)	4 m (visible), 1 m (panchromatic) resolution; 11 km swath	26 days	Changes in human infrastructure, Development patterns, Migration patterns, Agricultural variations, Urban/Rural interchange
	SEASTAR (Orbview-2)	1997	SeaWiFS (Sea-viewing Wide Field Sensor)	1.1 km (local area coverage) 4.5 km (global area coverage) resolution; 285 km swath	1 day	Changes in phytoplankton, Designed to provide global coverage of the oceans on a regular basis
	GeoEye-1	2008	Simultaneous panchromatic and multispectral camera	0.41 m resolution. 15.2 km swath	11 days	Earth imagining
	Worldview-1	2007	Panchromatic camera	0.5 m spatial resolution	1–2 days	Earth imagining, defense and intelligence
	Worldview-2	2009	Panchromatic camera	0.5 m spatial resolution	1 day	Spectral analysis, mapping and monitoring, land-use planning, disaster relief, defense and intelligence

Table F-2. Remote Sensing Satellite Platforms in the United States

Series	Satellite	Launch date	Environmental sensor	Specifications (resolution, swath,	Temporal resolution	Applications
Future Satellites	GeoEye-2	2013	Simultaneous panchromatic and multispectral camera	25 cm spatial resolution	4–5 days	Earth imaging
U.S. Earth Observation System (EOS) Satellites	TERRA	1999	ASTER (Advanced Spaceborne Thermal Emission and Reflection Radiometer)	15 m (VNIR), 30 m (SWIR), 90 m (TIR); 60 km swath	4–16 days By request	Infrastructure Changes, Residential Developments, Deforestation/Reforestation, Harvest, Flood Area, Landslides & Mass Movements
			MODIS (Moderate Resolution Imaging Spectro-Radiometer)	250 m (bands 1-2), 500 m (bands 3-7), 1,000 m (bands 8-36); 2,330 x 10 km swath	1–2 days	Forest Fires, Regional Harvest/Cycles, Plankton Blooms, Sediment Plumes, Maps extent of snow and ice brought by winter storms and frigid conditions
			MISR (Multi-angle Imaging Spectro-Radiometer)	275 m resolution; 360 km swath	9 days	Smoke Plumes, Regional Air Quality, Climate, Regional Forest Canopy Structure
			CERES (Clouds and Earth's Radiant Energy System)	20 km resolution	Daily	Cloud/radiation flux measurements for models of oceanic and atmospheric energetics
			MOPITT(Measurement of Pollution in the Tropo-sphere)	22 km horizontally and 3 km vertically; 640 km swath	3–4 days	Measurements of pollution in the troposphere, Used to determine the amount of Carbon dioxide and methane
	AQUA	2002	MODIS(Moderate Resolution Imaging Spectro-Radiometer)	250 m (bands 1-2), 500 m (bands 3-7), 1,000 m (bands 8-36); 2,330 x 10 km swath	1–2 days	Forest Fires, Regional Harvest/Cycles, Plankton Blooms, Sediment Plumes, Maps extent of snow and ice brought by winter storms and frigid conditions
			CERES(Clouds and Earth's Radiant Energy System)	20 km spatial resolution	Daily	Cloud/radiation flux measurements for models of oceanic and atmospheric energetics
			AMSR/E (Advanced Microwave Scanning Radiometer)	Ranging from 56 km (at 6.925 GHz) to 5.4 km (at 89.0 GHz); 1,445 km swath	Daily	Cloud properties; radiative energy flux; precipitation; land surface wetness; sea ice; snow cover; sea surface temperature; sea surface wind fields

Table F-2. Remote Sensing Satellite Platforms in the United States

Series	Satellite	Launch date	Environmental sensor	Specifications (resolution, swath,	Temporal resolution	Applications
			AIRS (Atmospheric Infrared Sounder)	13.5 km (IR) and 2.3 km (VIS/NIR); 1,650 km swath	Daily	Measures atmospheric temperature and humidity; land and sea surface temperatures; cloud properties; radiative energy flux
			AMSU (Advanced Microwave Sounding Unit)	40 km; 1,650 km swath	Daily	Measures atmospheric temperature and humidity
			HSB (Humidity Sounder for Brazil)	13.5 km; 1,650 km swath	Daily	Aimed at obtaining humidity profiles throughout the atmosphere
	AURA	2004	HIRDLS (High Resolution Dynamic Limb Sounder)	Profile spacing 500 km horizontally (50 lat) x 1 km vertically; averaging volume for each data sample 1 km vertical x 10 km across x 300 km along line-of-sight	Daily	Global distribution of temperature, chemical processes, global distribution and interannual variations of aerosols, cirrus, and PSCs, tropospheric cloud heights, tropospheric temperature, atmospheric dynamics
			MLS (Microwave Limb Sounder	5 km cross-track x 500 km along-track x 3 km vertical are typical values.	Daily	Ozone depletion, tropospheric ozone, climate change, volcanic effects
			OMI (Ozone Monitoring Instrument)	13 x 24 km spatial resolution,	Daily	Recovery of Ozone Layer, criteria air pollutants, volcanic ash and sulfur dioxide, ozone profiles, chemistry of stratosphere and troposphere
			TES (Tropospheric Emissions Spectrometer)	0.53 x 5.3 km spatial resolution	Daily	Biogeochemical cycles between lower and upper atmosphere, distribution and lifetimes of CFCs, global climate modification caused by increases in radiative active gases, changes in distribution of tropospheric ozone, natural sources of trace gases (i.e. methane, nitrogen oxides, and sulfur compounds)

Table F-2. Remote Sensing Satellite Platforms in the United States

Series	Satellite	Launch date	Environmental sensor	Specifications (resolution, swath,	Temporal resolution	Applications
	TRMM	1997	PR (Precipitation Radar)	3.1 mile horizontal spatial resolution, 154 mile swath	Daily	Create 3-Dimensional maps of storm structure, intensity, rain distribution and type, and storm depth
			TMI (TRMM Microwave Imager)	547 mile swath	Daily	Quantify water vapor, cloud water, and rainfall intensity in the atmosphere
			VIRS (Visible and Infrared Scanner)	0.63 to 12 mm spectral resolution, 833 km swath	Daily	Estimate precipitation and cloud temperature
			CERES (Cloud and Earth Radiant Energy Sensor)	No longer functioning		
			LIS (Lightning Imaging Sensor)	Detects 90% of all lightning strikes within field of view	Daily	Survey lightning and thunderstorm activity
NOAA Environmental Satellites Series	NOAA-N	2011	AVHRR/3 (Advanced Very High Resolution Radiometer)	1.09 km spatial resolution at nadir, 6 channels	Daily	Daytime and nighttime cloud and surface mapping, land-water boundaries, detection of snow and ice, sea surface temperature
			HIRS/3 (High Resolution Infrared Radiation Sounder)	20 x 19 km spatial resolution at nadir, 20 channels	Daily	Atmospheric temperature in cloud-free conditions
			AMSU-A (Advanced Microwave Sounding Unit-A)	40 km spatial resolution, 1,690 km swath	Daily	Global atmospheric temperature profiles and cloud presence
			MHS (Microwave Humidity Sounder)	16 km field of view, 5 channels	Daily	Measure profiles of atmospheric humidity
			SBUV/2 (Solar Backscatter Ultraviolet Radiometer)	160–400 nm spectral resolution, radiometric resolution of 1 nm	Daily	Ozone concentration distribution and concentration in the stratosphere
			SEM-2 (Space Environment Monitor)	N/A	Daily	Properties of the Earth's radiation belt and flux of charged particles and solar wind occurrence
Other U.S. Environmental-observing Satellites	GOES I-M	2001	Imager	5 channels, 0.65–12 um spectral resolution	Daily	Radiant and solar-reflected energy from the Earth

Table F-2. Remote Sensing Satellite Platforms in the United States

Series	Satellite	Launch date	Environmental sensor	Specifications (resolution, swath,	Temporal resolution	Applications
			Sounder	19 channels, 50 km horizontal resolution	Daily	Atmospheric temperature, moisture profiles, cloud surface temperatures, and ozone distribution
	GOES N-P	2006	Imager	5 channels, 0.52–13.7 um spectral resolution	Daily	Radiant and solar-reflected energy from the Earth
			Sounder	19 channels, 0.7–14.71 um spectral resolution	Daily	Atmospheric temperature, moisture profiles, cloud surface temperatures, and ozone distribution
			SEM-2 (Space Environmental Monitor)	10–126 nm spectral resolution, 5 channels	Daily	Intensity and duration of solar flares, changes in ionospheric conditions
			SXI (Solar X-ray Imager)	5 x 5 arc-sec pixel size, 42 x 42 arc-min field of view	Daily	Space weather forecasting
Future Satellites	SMAP	2015	N/A	N/A	N/A	Soil Moisture and freeze/thaw processes
	ICESat-II	2016	N/A	N/A	N/A	Polar ice-sheet distribution and change, large-scale biomass and biomass change
U.S./French Jason/Ocean Surface Topography Mission (OSTM) Series	Jason-1 and 2	Jason-1 (2001), Jason-2 (2008)	Poseidon-3 radar altimeter	N/A	10 days	General ocean circulation and hydrological cycles
			AMR (Advanced Microwave Radiometer)	3 channels	10 days	Atmospheric water vapor content
Future Satellites	Jason-3	2013	N/A	N/A	N/A	General ocean circulation and hydrological cycles
U.S./Argentina Satellite de Aplicaciones Cientific (SAC) series	SAC-C	2000	GOLPE (GPS Occultation and Passive Reflection Experiment)	N/A	16 days	Earth's gravity field
			SHM (Scalar Helium Magnetometer	N/A	16 days	Earth's geomagnetic field and related sun-Earth interactions

Table F-2. Remote Sensing Satellite Platforms in the United States

Series	Satellite	Launch date	Environmental sensor	Specifications (resolution, swath,	Temporal resolution	Applications
			MMRS (Multispectral Medium Resolution Scanner)	N/A	7–9 days	Observe terrestrial and marine biosphere
			HRTC (High Resolution Technological Camera)	N/A	16 days	Remote imaging over Argentina
			ICARE (Influence of Space Radiation on Advanced Components	N/A	10 days	High energy radiation environment
			Whale Tracker Experiment	N/A	16 days	Track the migratory route of the Franca Southern Right Whale
			HCS (High Sensitivity Camera)	N/A	16 days	Electrical storm detection and forest fire mapping
	SAC-D/Aquarius	2011	MWR (Microwave Radiometer)	40 km spatial resolution, 90 km swath	7 days	Precipitation, wind speed, sea ice concentration, water vapor
			NIRST (New Infrared Sensor)	3 channels, 180 km swath, 350 km resolution	7 days	Fire hot spots, sea surface temperature
			ROSA (Radio Occultation Sounder for Atmosphere)	300 km horizontal resolution, 300 km vertical resolution	7 days	Atmospheric temperature and humidity

Sources: Center for Earth Science Information Network, Columbia University, "A CIESEN Thematic Guide to Social Science Applications of Remote Sensing," October 2002.

Colorado State University, "Checklist of Environmental-Observing Satellites," Accessed at http://rammb.cira.colostate.edu/dev/hillger/environmental.htm.

Krebs, G.D., "Gunter's Space Page," Accessed at http://space.skyrocket.de/index.html.

ESA Earth Observation Missions, Accessed at http://www.esa.int/esaMI/Operations/SEMVSB8ZMRE_0.html.

NASA, "Index of Past, Current, and Future Missions," Accessed at http://www.nasa.gov/missions/index.html.

Table F-3. International Remote Sensing Satellite Platforms

Series	Satellite	Launch date	Sensor	Specifications	Temporal resolution	Derived capabilities/products
French Satellite Probatoire de l'Observation de la Terre (SPOT) Series	SPOT-4 and 5	SPOT-4 (1998), SPOT-5 (2001)	Two HRV-IR (High Resolution Visible, Infrared) push-broom sensors.	20 m (Visible, Near Infrared), 10 m (panchromatic) spatial resolution; 60 km swath	26 days	Deforestation, Suburban/Urban land use changes, Residential Development, Coastal Pollution, Water resource pollution monitoring, Snow and Ice mapping, Harvest forecasting, Conservation monitoring, Hazard prediction, Landslide hazards, Forest damage assessment
Future Satellites	SPOT-6 and 7	2012	Panchromatic and multispectral imaging cameras	10 m spatial resolution, 4 bands, 60 km swath	N/A	High-resolution, wide swath imagery
	SPOT-7	2014				
European Remote Sensing (ERS) Satellites	ERS-2	1995	AMI (Active Microwave Instrumentation)	30 m (SAR) 50 km (Scatterometer) spatial resolution; 80–100 km swath (SAR-Image mode); 5 km swath (SAR-Wave mode), 500 km swath (Scatterometer mode)	3 day, 35 day, or 168 day cycles	Alterations and observations in ocean, land, ice, atmosphere, and climate, Flood activity, Changes in ocean activity, coastal regions and ice caps
			ATSR-M (Along Track Scanning Radiometer with Microwave Sounder)	1 km (IR), 22 km (Microwave) spatial resolution; 500 km swath		
			GOME (Global Ozone Monitoring Experiment)	40 x 2 km 40 x 320 km spatial resolution; 960 km swath		
			AATSR (Advanced Along Track Scanning Radiometer)	0.5 km spatial resolution, 500 km swath		

Table F-3. International Remote Sensing Satellite Platforms

Series	Satellite	Launch date	Sensor	Specifications	Temporal resolution	Derived capabilities/products
Indian Remote Sensing (IRS) Satellites	IRS-P6/ResourceSat-1	2003	LISS-IV (Linear Imaging Self-Scanning Sensor-IV)	5.8 m spatial resolution	5 days	Land and water resource management
			LISS-III (Linear Imaging Self-Scanning Sensor-III)	23.5 m spatial resolution	5 days	
			AWiFS (Advanced Wide Field Sensor)	56 m spatial resolution	5 days	
	IRS-P5/CartoSat-1	2005	Two Panchromatic Cameras	2.5 m spatial resolution, 30 km swath	5 days	High-resolution imagery
	IRS-2/CartoSat-2	2007	Panchromatic camera	1 m spatial resolution, 9.6 km swath	N/A	High-resolution imagery
	IRS-2A/CartoSat-2A	2008	Panchromatic camera	1 m spatial resolution, 9.6 km swath	N/A	
	IRS-P7/OceanSat-2	2009	OCM (Ocean Color Monitor)	50 km resolution, 1,420 swath	2 days	Ocean imagery
			SCAT (Scanning Scatterometer)	1,400–1,840 km swath	2 days	Global ocean coverage and wind vector data
	IRS-2B/CartoSat-2B	2010	Panchromatic Camera	1 m spatial resolution, 9.6 km swath	4 days	High-resolution imagery
	IRS-P6/ResourceSat-2	2011	AWiFS (Advanced Wide Field Sensor)	56 m spatial resolution	5 days	Land and water resource management
			LISS-III (Linear Imaging Self-Scanning Sensor-III)	23.5 m spatial resolution	5 days	
			LISS-IV (Linear Imaging Self-Scanning Sensor-IV)	5.8 m spatial resolution	5 days	

Table F-3. International Remote Sensing Satellite Platforms

Series	Satellite	Launch date	Sensor	Specifications	Temporal resolution	Derived capabilities/products
China (PR) Brazil Earth Resources Satellite (CBERS)/ZY-1 Series	ZY-2, 2B/ZY 1A, 1B, 1B2	2007	WFI (Wide Field Imager)	260 m spatial resolution, 2 bands	5 days	Global remote sensing imagery
			CCD Camera	20 m spatial resolution, 113 km swath	26 days	
			IR-MSS (Infra-red Multispec-tral Scanner)	80 m spatial resolution, 120 km swath	26 days	
			HRC (High-Resolution Panchromatic Camera)	N/A	5 days	
Future Satel-lites	ZY-1C	2011	Four Panchro-matic Cameras	N/A	N/A	Global remote sensing imagery
	ZY-1D	2013				
China (PR) Resource (CR) satel-lite/ZY-2 and ZY-3 series						
Future Satel-lites	ZY-3A	2011	N/A	N/A	N/A	High resolution mapping satellites
	ZY-3B	201?				
China (PR) Haiyang (HY)/Ocean Series	HY-1B/Ocean-1B	2007	N/A	N/A	N/A	Sea optical characteristics of China's coastal regions
China (PR) ShiYan (SY)/TanSuo (TS) Series	SY-1, 2, and 3	SY-1 (2004), SY-2 (2004), SY-3 (2008)	N/A	N/A	N/A	Earth Observation

Table F-3. International Remote Sensing Satellite Platforms

Series	Satellite	Launch date	Sensor	Specifications	Temporal resolution	Derived capabilities/products
China (PR) Remote Sensing Satellite (RSS)/Yaogan -Series	RSS-1, 2, 3, 4, 5, 6, 7, 8, 9, and 10	RSS-1 (2006), RSS-2 (2007), RSS-3 (2007), RSS-4 (2008), RSS-5 (2008), RSS-6 (2009), RSS-7 (2009), RSS-8 (2009), RSS-9 (2010), RSS-10 (2010)	N/A	N/A	N/A	Remote Sensing
Republic of China (Taiwan) Satellite (Rocsat)/FORMOsa Satellite (Formosat) Series	Rocsat-1, 2, and 3	Rocsat-1 (1999), Rocsat-2 (2004), Rocsat-3 (2006)	OCI (Ocean Color Imager)	N/A	N/A	Ocean imagery
			IPEI (Ionospheric Plasma and Electrodynamics Instrument)	N/A	N/A	Ocean imagery
Israeli Earth Resources Observation Satellite (EROS) series	EROS-A1	2000	CCD Camera	1.8 m spatial resolution, 13.5 km swath	N/A	Global Imagery
	EROS-B	2006	CCD/TDI Camera	0.7 m spatial resolution, 7 km swath	N/A	Very high resolution imagery
Future Satellites	EROS-C	2011	CCD/TDI Camera	0.7 m spatial resolution, 11 km swath	3 days	Very high resolution imagery
Canadian RADAR Satellite (Radarsat) Series	Radarsat-1	1995	SAR (Synthetic Aperture Radar)	8–100 m spatial resolution	24 days	High quality Earth image, nearly complete global coverage

Table F-3. International Remote Sensing Satellite Platforms

Series	Satellite	Launch date	Sensor	Specifications	Temporal resolution	Derived capabilities/products
	Radarsat-2	2007	SAR (Synthetic Aperture Radar)	1 m spatial resolution, 100 km swath	24 days	High quality Earth image, nearly complete global coverage
Future Satellites	Radarsat-Constellation	2015	SAR (Synthetic Aperture Radar)	N/A	12 days	High quality Earth image, nearly complete global coverage
Korean Multi-Purpose Satellite (Kompsat) Arirang Series	Kompsat-2	2006	Multispectral Camera	1 m spatial resolution, 15 km swath	14 days	High resolution imagery of the Korean peninsula
Future Satellites	Kompsat-3	2012	Multispectral Camera	N/A	N/A	High resolution imagery of the Korean peninsula
Italian Constellation of small Satellites for Mediterranean basin Observation (COSMO-SkyMed) Series	COSMO-1, 2, 3, and 4	COSMO-1 (2007), COSMO-2 (2007), COSMO-3 (2008), COSMO-4 (2010)	SAR (Synthetic Aperture Radar)	1–10 m spatial resolution, up to 520 km swath	N/A	Surveillance and monitoring data during international conflict, and environmental monitoring
European Space Agency (ESA) CRYOgenic SATellite (CryoSat) Series	CryoSat-2	2010	SIRAL (SAR/Interferometric Radar Altimeter)	N/A	N/A	Changes in marine ice thickness in polar oceans
			DORIS (Doppler Orbit and Radio Positioning Integration by Satellite	N/A	N/A	

Table F-3. International Remote Sensing Satellite Platforms

Series	Satellite	Launch date	Sensor	Specifications	Temporal resolution	Derived capabilities/products
Other non-U.S. Environmental-Observing Satellites	Envisat (Europe, ESA)	2002	ASAR (Advanced Synthetic Aperture Radar)	30–1,000 m spatial resolution (depending on mode), 5–400 km swath (depending on mode)	N/A	Ocean and Coast (Ocean Currents and Topography) Land (Landscape Topography) Snow and Ice (Snow and Ice)
			MERIS (Medium Resolution Imaging Spectrometer)	Resolution: Ocean-1,040 x 1,200 m, Land-260 x 300 m; 1150 km swath	3 days	Ocean and Coast (Ocean Color/Biology) Land (Vegetation) Atmosphere (Clouds/Precipitation)
			AATSR (Advanced Along Track Scanning Radiometer)	1 km spatial resolution, 500 km swath	N/A	Atmosphere (Clouds/Precipitation) Land (Vegetation) Ocean and Coast (Sea Surface Temperature)
			RA-2 (Radar Altimeter)	N/A	N/A	Snow and Ice (Sea Ice) Atmosphere (Winds) Land (Topography/Mapping) Ocean and Coast (Ocean Waves, Ocean Currents and Topography)
			MWR (Microwave Radiometer)	20 km spatial resolution, 20 km swath	N/A	Atmospheric temperature
			GOMOS	N/A	N/A	Ozone
			MIPAS (Michelson Inferometer for Passive Atmospheric Sounding)	3 km spatial resolution, 3 x 30 km swath width	N/A	Atmospheric properties (ozone, temperature, radiation, chemistry)

Table F-3. International Remote Sensing Satellite Platforms

Series	Satellite	Launch date	Sensor	Specifications	Temporal resolution	Derived capabilities/products
			SCIAMACHY imaging spectrometer	3 x 132 km vertical resolution, 32 x 215 km horizontal resolution, 100 km swath	N/A	Agriculture, Atmospheric ozone, solid Earth, Ocean and Coast
			DORIS (Doppler Orbitography and Radiopositioning Integrated by Satellite)	N/A	N/A	Envisat's tracking system
			LRR	350–800 nm spectral resolution	N/A	Monitoring tectonic/seismic activity and natural disasters
	Alsat (Algeria, Russia)	2002	Earth imaging cameras	32 m spatial resolution, 600 km swath	4 days	Disaster monitoring
	Monitor-E (Russia)	2005	Panchromatic imager	8 m spatial resolution, 90 km swath	N/A	Imaging
			Multi-band imager	20–40 m spatial resolution, 160 km swath	N/A	Imaging
	TerraSAR-X (Germany)	2007	SAR (Synthetic Aperture Radar)	1 m spatial resolution	2.5 days	Imaging
	RapidEye-1,2,3,4,5 (Germany)	2008	Multi-spectral imager (same sensor on each platform)	5 m spatial resolution, 77 km swath	1 day	Vegetation health, protein and nitrogen content in biomass
	THEOS (Thailand)	2008	Panchromatic imager	2 m spatial resolution, 22 km swath	26 days	Imaging

Table F-3. International Remote Sensing Satellite Platforms

Series	Satellite	Launch date	Sensor	Specifications	Temporal resolution	Derived capabilities/products
			Multispectral imager	15 m spatial resolution 90 km swath	26 days	Imaging
	GOSAT/Ibuki (Europe)	2009	TANSO (Thermal and Near-infrared Sensor for carbon Observation)	0.5 km spatial resolution, 1,000 km swath	3 days	Greenhouse gas observation
	TanDEM-x Germany)	2010	SAR (Synthetic Aperture Radar)	12 m spatial resolution	11 days	Generate accurate digital elevation maps (DEM)
Future Satellites	Rasat (Turkey)	2011	OIS (Optical Imaging System)	7.5 m (PAN) and 15 m (MS) spatial resolution, 30.7 km swath	N/A	Imaging

Sources: Center for Earth Science Information Network, Columbia University, "A CIESEN Thematic Guide to Social Science Applications of Remote Sensing," October 2002.

Colorado State University, "Checklist of Environmental-Observing Satellites," Accessed at http://rammb.cira.colostate.edu/dev/hillger/environmental.htm.

Krebs, G.D., "Gunter's Space Page," Accessed at http://space.skyrocket.de/index.html.

ESA Earth Observation Missions, Accessed at http://www.esa.int/esaMI/Operations/SEMVSB8ZMRE_0.html.

NASA, "Index of Past, Current, and Future Missions," Accessed at http://www.nasa.gov/missions/index.html.

ADDITIONAL RESOURCES

In addition to the above discussion on remote sensing technologies and capabilities, there are several key resources identified during the course of the study, such as general tutorials, applications, updated platforms, and data access archives.

Remote Sensing Tutorials

General tutorials provide both simple and complex explanations of the many remote sensing components. Both NASA and the Canada Centre for Remote Sensing (CCRS) have comprehensive and up-to-date tutorials.

- NASA, "Remote Sensing Tutorial," http://rst.gsfc.nasa.gov/Front/tofc.html.
- CCRS, "Fundamentals of Remote Sensing," http://ccrs.nrcan.gc.ca/resource/tutor/fundam/pdf/fundamentals_e.pdf.

Applications of Remote Sensing

The potential environmental, social, and political uses of remote sensing are vast and constantly expanding. The reports and sources below provide additional in-depth discussions and assessments on how remote sensing can meet the needs of policy and decision makers, especially in efforts to integrate conflict, instability, and fragility early warning with natural resource and environmental factors.

- Leeuw, J., et al., “The Function of Remote Sensing in Support of Environmental Policy,” http://www.mdpi.com/2072-4292/2/7/1731/pdf, July 2010.
- Sherbinin, A., et al., “A CIESEN Thematic Guide to Social Science Applications of Remote Sensing,” Center for International Earth Science Information Network (CIESEN). January 2006.
- Wigbels, L., Faith, G.R., Sabathier, V., “Earth Observations and Global Change,” Center for Strategic and International Studies, July, 2008.

Satellite Platforms and Sensors

Tables F-2 and F-3 above were created using information from reports, space program resources, and academic databases. Listed below are primary resources used. Most of these resources are updated frequently to provide near real-time databases of functioning satellite platforms.

- Center for Earth Science Information Network, Columbia University, “A CIESEN Thematic Guide to Social Science Applications of Remote Sensing,” October 2002.
- Colorado State University, “Checklist of Environmental-Observing Satellites,” http://rammb.cira.colostate.edu/dev/hillger/environmental.htm
- ESA Earth Observation Missions, http://www.esa.int/esaMI/Operations/SEMVSB8ZMRE_0.html
- NASA Index of Past, Current, and Future Missions, http://www.nasa.gov/missions/index.html.

Spatial Data Infrastructures

Additional GEOSS information and similar spatial data infrastructure initiatives can be found in the resources listed below.

Global Earth Observation System of Systems (GEOSS)

- http://www.epa.gov/geoss/index.htm (Homepage)

- http://geoportal.org/web/guest/geo_home (GEO Portal)
- http://usgeo.gov/(U.S. Contributions to GEOSS)

INSPIRE GeoPortal (prototype)

- http://www.inspire-geoportal.eu/index.cfm

Global Monitoring for Environment and Security (GMES)

- http://ec.europa.eu/enterprise/policies/space/gmes/

Additional Remote Sensing Data Archives and Links

- NASA, Remote Sensing Data and Information
  - http://rsd.gsfc.nasa.gov/rsd/RemoteSensing.html
- USGS, National Satellite Land Remote Sensing Data Archive
  - http://edcwww.cr.usgs.gov/archive/nslrsda/
- USGS Land Cover Institute
  - http://landcover.usgs.gov/landcoverdata.php
- USGS, Land Processes Distributed Active Archive Center
  - https://lpdaac.usgs.gov/
- European Space Agency, Data Products
  - http://earth.esa.int/dataproducts/

Appendix G
Analysis Aids, Models, Tools, and Systems

This study identified several analysis, models, tool suites, and early warning systems. An overview of these findings is summarized in this appendix. These analysis aids, tools, and systems provide insight into the existing US government capabilities for analyzing, assessing, predicting, and responding to conflict, instability, fragility, and/or environmental change. Table G-1 provides an overview of the main components of each tool including spatial coverage, data inputs, analytical processing, and available outputs. Projects and capabilities covered are generally listed in order of analysis approaches or tools, integration or monitoring, modeling, and early warning systems.

Following Table G-1, this appendix presents a brief profile of each analysis tool, detailing the architecture, purpose, primary users, and specific analysis techniques.

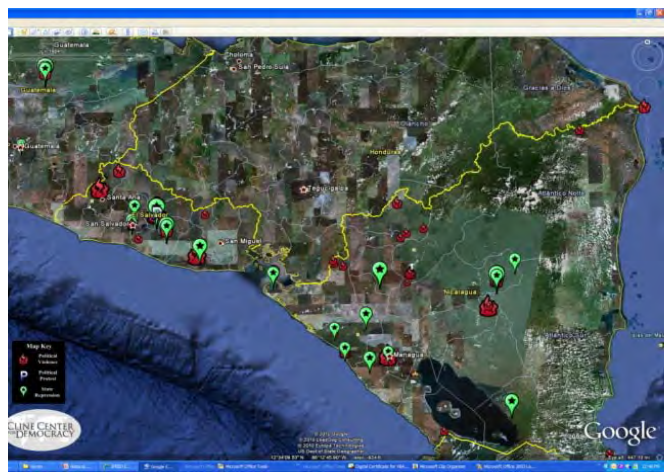
Table G-1. Overview of Efforts, Models, Tools, and Systems for Analyzing, Monitoring, or Predicting Conflict, Instability, or Fragility

Tool	Creator	Temporal Coverage			Spatial Coverage					Data Input or Generated						Analysis					Outputs					
		Past	Present	Future	Global	Regional	National	Sub-National	Environmental Component	SME Input/Operational Theory	Case Studies	Survey/Polling	Event Recording	Media Reporting	Quantitative/Statistical	Data Compilation/Synthesis	Geospatial	Discussion-Based	Agent-Based	Scenario Planning	Reports/Briefings	Databases	Charts/Graphs	Maps	Decision Metric	Predictions/Forecasts
PPNRA/SPEED	ERDC-CERL/Univ. of Illinois	✓	✓			✓	✓	✓	✓		✓		✓	✓		✓	✓				✓	✓		✓		
GlobalNet	NCSA, University of Illinois	✓	✓	✓	✓	✓	✓	✓		✓	✓			✓	✓	✓	✓				✓	✓	✓	✓	✓	✓
ICAF	Department of State	✓	✓				✓		✓	✓	✓				✓			✓			✓					
MPICE	USACE	✓	✓				✓		✓	✓		✓		✓	✓	✓				✓	✓				✓	
Serengeti	AFRICOM	✓	✓			✓	✓	✓	✓	✓	✓	✓			✓	✓	✓				✓	✓	✓	✓		
FACT III	CAA	✓		✓	✓	✓	✓		✓						✓	✓								✓		✓
USAID Alert Lists	USAID	✓	✓		✓	✓	✓			✓		✓			✓	✓					✓				✓	
Senturion	Sentia Group			✓			✓	✓		✓									✓	✓					✓	✓
NOEM	AFRL	✓	✓	✓			✓	✓		✓					✓	✓			✓	✓			✓		✓	✓
FEWS-NET	USAID		✓	✓		✓	✓	✓	✓	✓		✓			✓	✓	✓				✓			✓		✓
ICEWS	DARPA	✓	✓	✓	✓	✓	✓			✓			✓	✓	✓	✓	✓		✓	✓	✓		✓		✓	✓
CCAPS	University of Texas at Austin	✓	✓			✓	✓	✓	✓	✓					✓	✓	✓				✓	✓		✓		
SCAD	CCAPS, University of Texas at Austin	✓	✓			✓	✓	✓					✓	✓		✓	✓					✓				

PROACTIVE PEACEBUILDING WITH NATURAL RESOURCE ASSETS PROJECT AND SPEED

Developer	Engineering Research and Development Center-Construction Engineering Research Laboratory; Cline Center for Democracy, University of Illinois; sponsored by the Army Environmental Policy Institute
Analysis type	Media capture and coding; geospatial analysis of events; and comparative case study analysis
Purpose	Understand relationships between natural resource activities and civil unrest
Used by	US government practitioners; Academia

Data



The Proactive Peacebuilding with Natural Resource Assets (PPNRA) project analysis approach uses two types of data: (1) case studies of environmental issues compiled by the Environmental Law Institute and the United Nations Environmental Program, and (2) media reports from the British Broadcasting Corporation summary world broadcasts (SWB) from the 1970s to the present. These media reports are supplemented by other sources and then captured in a human coded event database, known as Social, Political, and Economic Event Database (SPEED).

Analysis

The PPNRA project's goal is to identify the linkages between natural resources and civil unrest. To do so, the analysis first identifies a set of diverse nations as "pilots." For each country, the data described above are collected. Then, the comparative approach examines the conflict and natural resource case studies in the context of the geo-referenced event data from the SPEED event database. The PPNRA effort is analyzing the conflict event data, using spatial, temporal, and economic factors to identify, explore, and gain insight from the linkages with natural resources.

Outputs

The PPNRA effort is studing the linkages between the conflict and natural resource, with an emphasis on how conflict interventions or resolutions are linked to the underlying natural-resource-related issues. The goal of this analysis effort is to better understand ways to implement proactive diplomatic, information, military, and economic (DIME) operations when natural-resource-related issues are involved in national security interests.

PPNRA's outputs is to include a quantitative analyses of linkages between conflict and natural resources and a subsequent analysis report.

Architecture

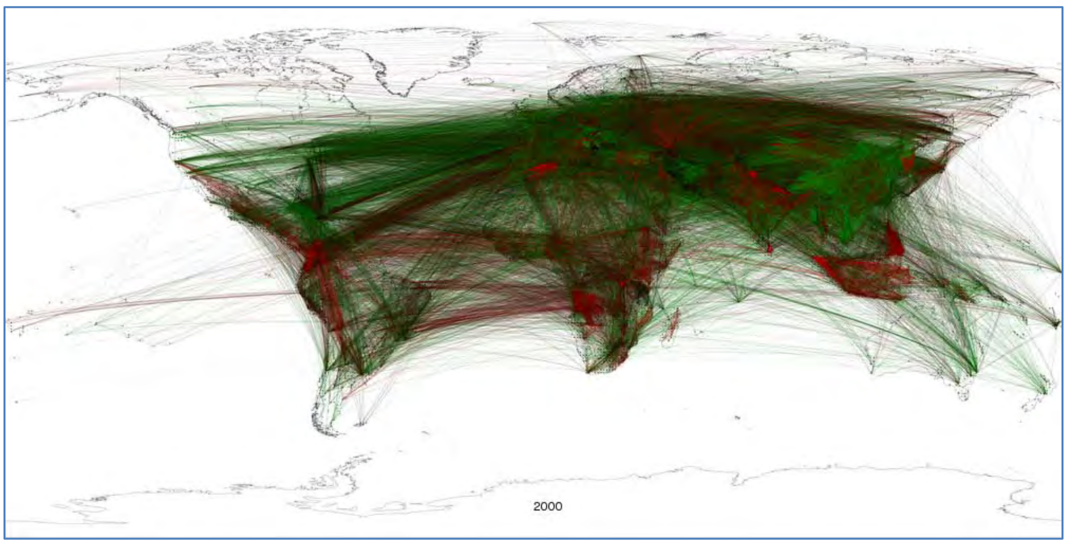
PPNRA project used SPEED event data to mine, transform, and distill information from global news reports, such as the BBC summary of world broadcasts. SPEED stores all the event data used in the analysis effort. SPEED also uses geocoding to track locations of conflict events and natural resource issues.

GLOBALNET PROJECT

Developer	National Center for Supercomputing Applications (NCSA), University of Illinois
Analysis type	Predictive modeling, geospatial, temporal, and sentiment analysis
Purpose	Monitor and forecast global stability and human social terrain on a scale from global to local
Used by	Ongoing research effort

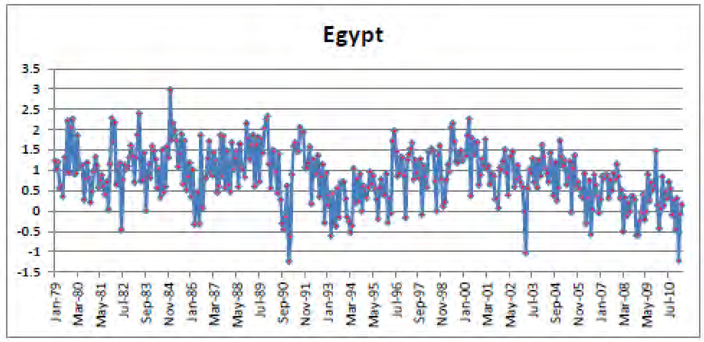
Data

The NCSA GlobalNet project searches global news data archives from Foreign Broadcast Information Service (Open Source Center), Summary of World Broadcasts, historical news archives, a real-time continuous all-web news crawl, and a wide range of other data sources such as technical reports. A fully automated analytical pipeline, leveraging massive shared memory supercomputing power, identifies, disambiguates, and constructs biographical profiles of all people, organizations, dates, locations, actions, and tonal indicators, and all of the interactions among them, to construct a network knowledgebase on the order of hundreds of trillions of links.



This knowledge can be cross-sectioned to construct a stability measure for any actor, such as a country or terror group.

Analysis



The networks produced through GlobalNet create a temporally and spatially explicit sample of factual information regarding public perception of events, people, organizations, etc. Paired with a variety of modeling and simulation techniques, data from the GlobalNet knowledgebase can provide analysts with non-traditional methods of interacting with and understanding societal interaction on a local to global scale.

GlobalNet analysis has already yielded intriguing results when studying the tone and sentiment of Egypt and other Middle Eastern societies during the Arab Spring as well as estimating Osama Bin Laden's hiding place to within 200 kilometers.[1]

Outputs

Network based simulations and analyses within GlobalNet produce unique "tonal signatures" of societal views towards a wide range of actors. As opposed to a more traditional approach of compiling event databases, GlobalNet offers a new near-real time tool for advanced warning and forecasting instability. Overtime, tonal signatures produce long-term projections showing progressive change in contentedness or longer-term gradual nation destabilization.

Architecture

GlobalNet utilizes a shared memory, supercomputer platform named Nautilus and numerous advanced analysis techniques produce networks, with "10 billion people, places, things, and activities connected by over 100 trillion relationships."[2] It connects the data points from these huge number of compiled lists of people, organizations, actions, concepts, dates, and locations together into a networked knowledgebase permitting temporally and spatially based inquiry.[3,4]

---

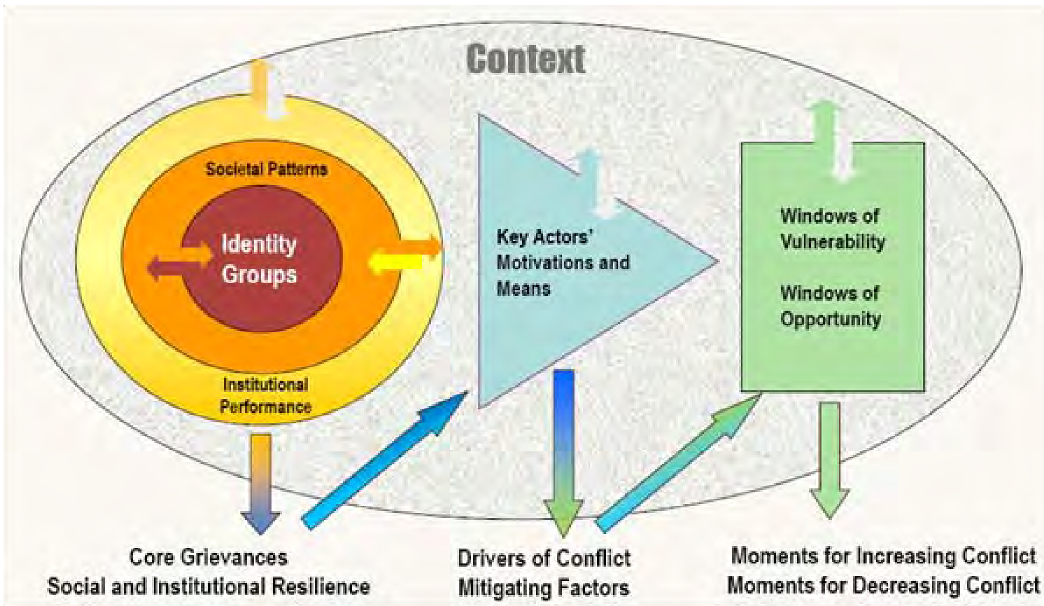
[1] Leetaru, Kalev. "Culturomics 2.0: Forecasting large-scale human behavior using global news media tone in time and space" First Monday [Online], Volume 16 Number 9 (August 17, 2011).

[2] Rockett, Caitlin Elizabeth, Petascale Humanities: Supercomputing Global News Media, September 5, 2011, National Institute for Computational Sciences, www.nics.tennessee.edu/leetaru

[3] Kalev Leetaru. The *GlobalNet Project-Future Directions.* (NCSA, University of Illinois, 2011).

INTERAGENCY CONFLICT ASSESSMENT FRAMEWORK

Developer	USG Interagency, led by US Department of State and US Agency for International Development (USAID)
Analysis type	Discussion-based decision framework; Joint, systematic analysis from different perspectives (e.g., USG desk officers)
Purpose	Develop shared understanding across USG of deep causes of conflict and resilience
Used by	DoD, US Department of State, USAID, other USG departments and agencies



Data

The Interagency Conflict Assessment Framework (ICAF) provides a systematic framework for the collection and analysis of existing secondary source material and new primary source data collected by teams of USG officials interviewing 300–1,000 country residents over a period of 5 days.

Analysis

This is a multi-stage analysis with skilled facilitation results in consensus findings of drivers and mitigaters of conflict. The first stage is a Washington, DC, based

[4] Kalev Leetaru. *The NCSA GlobalNet Project and DARPA's ICEWS Initiative: A Comparison.* (NCSA, University of Illinois, 2011).

ICAF analysis workshop. USG interagencies with some country expertise participate. The most significant output is a list of what policy-makers “don’t know” concerning deep causes of conflict and stability in the country. The second stage involves in-country interviews and an analysis workshop led by ICAF experts with teams comprised of US Embassy staff and other international partners.

Outputs

ICAF outputs include a jointly achieved shared understanding among the USG interagency in Washington DC and at in-country Embassy Posts (an experience, not just a report). In-country ICAF applications also provide new data, and identify potential points of entry for USG policy, strategy and programming compiled in form of a written report.

Architecture

ICAF provides USG policy makers in disparate offices and functionalities the opportunity to hear what other offices are thinking and doing with regard to the country under consideration, ultimately generate a country-centric network of USG officials. Requests for ICAFs are made via Front Channel Cables by ambassadors or heads of regional bureaus to the Coordinator for Reconstruction and Stabilization.[5,6]

[5] *The Interagency Conflict Assessment Framework: The USG’s Interagency Tool for Conflict Assessment*, www.mors.org/UserFiles/file/2010%20Interagency/Irmer%20presentation%20REDUC%20(2).pdf.

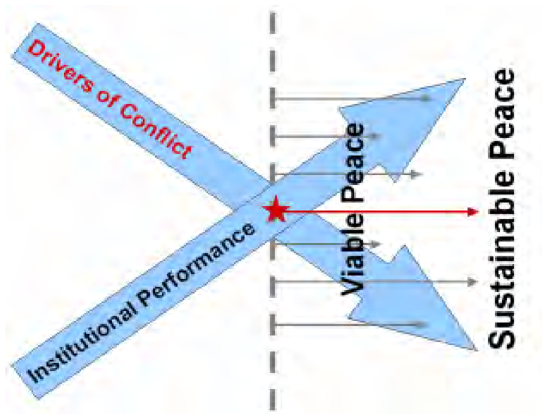
[6] US Department of State, *Interagency Conflict Assessment Framework*, http://pdf.usaid.gov/pdf_docs/PCAAB943.pdf.

MEASURING PROGRESS IN CONFLICT ENVIRONMENTS

Developer	US Army Corps of Engineers
Analysis type	Data collection and metric tracking
Purpose	Measure progress during stabilization and reconstruction operations
Used by	Policymakers, analysts, planners, and program and project implementers

Data

The Measuring Progress in Conflict Environments (MPICE) uses indicators to track progress. Each indicator is supported by one or more measures, which in turn are supported by data streams. MPICE uses four methods to collect data: content analysis, quantitative data, survey and polling data, and expert knowledge.



Analysis

MPICE tracks progress in five sectors:

1. Political moderation and stable governance
2. Safe and secure environment
3. Rule of law
4. Sustainable economy
5. Social well being.

For each of these sectors, MPICE uses indicators to track progress toward a specific, outcome-oriented goal. Indicators are broken down into two types: conflict drivers and institutional performance. The first tracks the motivations and means for violent conflict; the second tracks the capacity of institutions to overcome conflict peacefully.

Outputs

MPICE outputs the current status of indicators. It also allows users to review how indicators have changed over time, allowing them to track progress toward each goal.

Architecture

As MPICE pulls from many data sources, including polling data and expert knowledge, some of the data used are not necessarily open source or automatically accessed by the tool.[7]

Prior iteration of MPICE, included a software package that ran on a desktop environment. The old tool had a customizable user interface with capabilities to export the results into many common desktop formats (Microsoft Word, Excel, etc.). Currently, the MPICE tool's software is undergoing redevelopment so further information on its new architecture is still pending.[8]

[7] John Agoglia, Michael Dziedzic, and Barbara Sotirin, *Measuring Progress in Conflict Environments (MPICE): A Metrics Framework* (US Institute of Peace Press, 2010).

[8] Personal communication with Ms. Steffenie Fries, US Army Corps of Engineers.

SERENGETI

Developer	Africa Command (AFRICOM)
Analysis type	Data collection and analysis
Purpose	An Africa-centric data repository and analytic interface
Used by	AFRICOM analysts

Data

SERENGETI is designed to enable the flexible storage of Africa-centric datasets of any size or type. Data are of two types: external, open-source data and internal. Open-source data are primarily pulled from the web and consist of many forms.

Analysis

SERENGETI uses the data above to provide analysis of emerging events "vis-à-vis visual alerts and customized trackers across multiple domains." The tool is flexible, allowing analysts to set up various types of analyses and experiment with different hypotheses and analytical techniques.

Outputs

SERENGETI does not have a specific output, but is flexible enough to allow analysts to gather and analyze data as needed. It uses an analyst interface called Savanna, which allows analysts to generate maps, model human terrain, search data resources and visualize results, and build automated reports.

Architecture

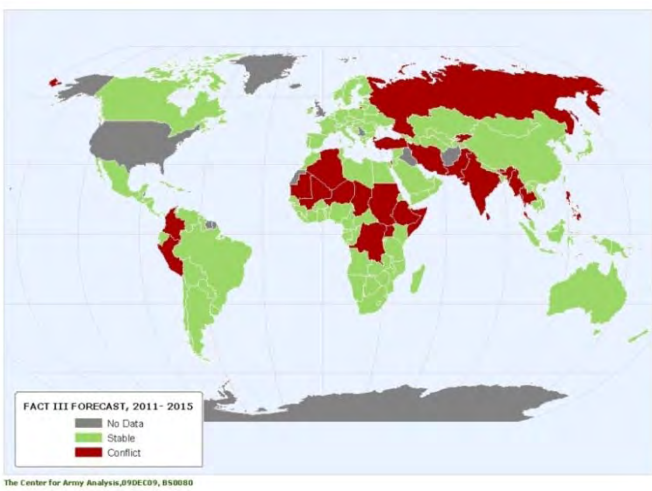
SERENGETI is an architecture upon which AFRICOM analysts can compile and analyze data in a systematic way. Currently, many aspects of the architecture are likely proprietary so other clients are unlikely to be able to directly port it. However, the tool's implementing framework and individual pieces may be accessible.[9]

[9] SERENGETI, "A Unique Architecture: A Unique Organization," *DIA Communiqué*, 2010.

FORECAST AND ANALYSIS OF COMPLEX THREATS III

Developer	Center for Army Analysis (CAA)
Analysis type	Predictive modeling
Purpose	Forecast internal conflict within countries around the world
Used by	Ongoing research effort of CAA

Data



The Forecast and Analysis of Complex Threats (FACT) III model uses 24 indicators to project fragility within countries. These indicators are drawn from a range of public data sources, including the Central Intelligence Agency World Factbook, the US Census Bureau, and the World Bank Development Indicators. FACT III uses tabular national data. The indicators include the following:

Autocraticness	Largest Religion
Civil Rights	Life Expectancy
Democraticness	Political Instability
Durability of Government	Political Instability (five years)
Ethnic Fractionalization	Political Rights
Ethnic Majority	Political Terror
Ethnic Ratio	Polity
Forested Area	Population Density
Gross National Income per Capita	Religious Fractionalization
Hydrocarbon Exports	Religious Majority
Infant Mortality Rate	Religious Ratio
Largest Ethnicity	Rough Terrain

Analysis

FACT III relies on a four-step method to project internal conflict:

1. Identify the status of all 24 indicators for all countries for each year between 1993 and 2002.

2. For each year, identify the conflict status of each country: conflict, uncertain, and stable.

3. Project forward the status of all 24 indicators for each country (via linear regression techniques).

4. Predict the conflict state of each country, through a “K-Nearest Neighbor” technique. This consists of assigning a score for each future year of every country on the basis of its two “nearest neighbors.” For example, if the indicators for Afghanistan (2020) are most similar to Bolivia (2000) and Sweden (1998), it will take the average conflict score of the two.

Outputs

FACT III outputs projections of internal conflict within countries. Countries are classified as either in conflict, uncertain, or not in conflict. Projections are tabular and country-level. Projections are given in 5-year increments, out to 2025.

FACT III was 91 percent accurate when benchmarked against historical data (1993–97 data used to forecast 1998–02; 1998–02 used to forecast 2003–07). However, FACT III did not anticipate the Middle East unrest of early 2011.

Currently, the FACT III model is under development and not actively used by government decision makers to predict conflict.

Architecture

The FACT III model uses Microsoft Access to manage all historic indicators and future projections. The model does not actively update or access data. The model structure is not open source, but if made available, could likely be built upon.[10]

---

[10] S. Binkley, “Forecast and Analysis of Complex Threats III: Condensed Slides for Army Environmental Policy Institute (AEPI),” (briefing, December 2010).

USAID ALERT LISTS

Developer	USAID
Analysis type	Data collection, analysis, and integration via indexing
Purpose	Ranks countries in terms of overall instability and fragility to better inform development sector emphasis.
Used by	Internal agency users

Data

Creating the Fragility and Instability Alert Lists requires access to security, political, economic, and social data that has both global and temporal coverage. In designing the framework for compiling these lists, a range of possible indicators were proposed, and the eventual 33 indicators were selected based upon relevance to USAID missions as well as data coverage, accessibility, robustness and authority.[11] Some indicators selected require indirect measures to obtain relevant data that is otherwise inaccessible or too costly to collect directly. Indirect measures include public opinion surveys, SMEs, observable outcomes, and similar country comparisons.

Recent discussion over the design of the Alert List framework has been focused on incorporating natural resource and environment factors/indicators in the analysis process. In January 2011, a USAID Workshop considered five potential natural resource and environmental variables to include in future analysis:

- Deviance from Gross Domestic Product-predicted air quality,
- Environmental burden of disease,
- Agriculture-relevant weather shocks,
- Non-economic impacts of natural disasters, and
- Government control of high-value natural resources.[12]

[11] USAID, Measuring Fragility, Indicators and Methods for Rating State Performance, June 2005.

[12] USAID, Conflict, Fragility, and The Environment: A USAID/DCHA/CMM Experts' Workshop, Summary Report, May 2011.

Analysis

Instability risk scores are the ratio of a nation's probability of experiencing instability compared to the average probability among all OECD member countries. The USAID approach to calculating these risk scores is similar to methods used for the University of Maryland, Peace and Conflict Ledger. The Fragility Alert Lists is generated using a principal component analysis (PCA) approach. Component scores are compiled in four different domains of government activity: security, political, economic, and social. These scores are calculated through statistical analyses performed on 33 different fragility/instability indicators that are individually weighted based upon their respective effectiveness and legitimacy attributes. After scoring, countries are further classified by quintiles in categories: highest fragility, high fragility, moderate fragility, some fragility, and low fragility.

Outputs

USAID creates internal annual reports that include alert lists for both fragility and instability. These are synthesized in a Unified Fragility-Instability Matrix that compares the two approaches on a country-by-country basis. The Alert List Reports are sensitive but unclassified so they are not available to the public. Both lists are used to inform USAID analysis and decisions for their development programs.

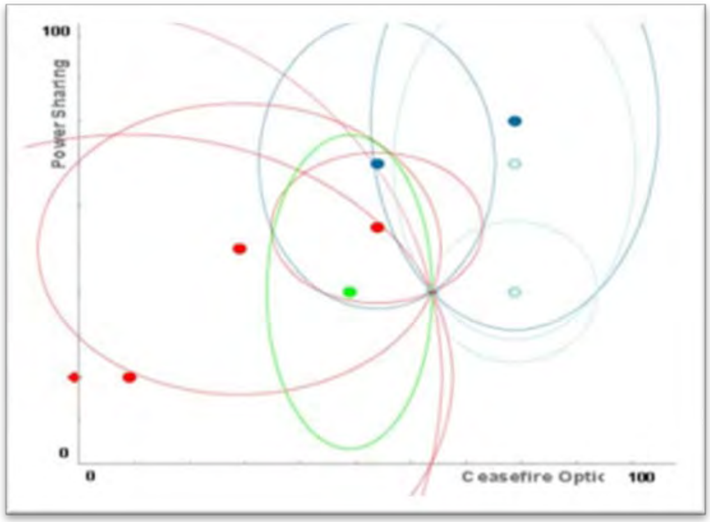
Architecture

Aside from the aforementioned conceptual constructs and PCA analysis, no dedicated software architectures are used in creating and generating the Fragility and Instability Alert Lists. Basic statistical analyses are employed in developing the lists using standard desktop software packages.

SENTURION

Developer	Sentia Group
Analysis type	Agent-based predictive model
Purpose	Predict the outcome of complex political events and detail why outcomes occur on the basis of actor motivations
Used by	National Defense University, other DoD, and commercial clients

Data



Senturion uses SME interviews to generate the data used in the model. SMEs identify the critical stakeholders, their positions on policy issues, their influence over other stakeholders, and the strength of their commitment or advocacy of a policy position. The Senturion software helps facilitate this process. SME generated data are highly accurate in capturing a snapshot of the current political situation. However, it is less accurate when being used as a predictive tool.

The SME data are specific to the current state of the situation modeled and cannot be extrapolated to other situations. It is not publically available.

Analysis

Senturion is an agent-based model, meaning it uses mathematics to simulate the behavior of “agents,” or individuals. These agents must abide by a set of rules. Senturion’s rules synthesize theories from political science, microeconomics, game theory, and spatial bargaining. Senturion uses the SME data to form the behavior of the agents, as described above.

In addition to predicting the outcomes of political events, Senturion explains why it makes the predictions. Senturion’s algorithms break each agent’s political calculus into sub-elements. Users can track these sub-elements to explain why a particular decision or political outcome arises.

Outputs

Senturion predicts the outcomes of complex political events, as noted, explaining why stakeholders will reach a particular decision or political outcome. The model can predict events out to about 2 years, after which it becomes increasingly likely that the stakeholders will change. Sentia has used Senturion to accurately model the outcomes of many complicated political situations, including

- Operation Iraqi Freedom and its aftermath,
- the January 2005 Iraqi elections, and
- the Palestinian leadership transition after Yassar Arafat's death.

Senturion is not currently part of any standardized government analysis or forecasting process. Gathering the required SME data through interviews is time consuming and costly.

Architecture

Senturion is a highly complex, proprietary software package. Its associated graphical user interface allows users to explore the political landscape and evaluate the potential of different intervention strategies. Users can export Senturion's outputs to other software packages. The model is more than a decade old and builds upon previous models, including Policon. The Sentia Group continues to market and develop Senturion.[13]

[13] M. Abdollahian et. al., *Senturion—A Predictive Political Simulation Model*, Center for Technology and National Security Policy, July 2006.

NATIONAL OPERATIONAL ENVIRONMENTAL MODEL

Developer	Air Force Research Laboratory
Analysis type	System Dynamics, Agent-based, and Game Theory modeling and analysis
Purpose	Provide model for strategic analysis and assessment to better understand today's complex operational environment.
Used by	DoD intelligence analysts, decision makers, and researchers

Data

Image Source: AFRL "The National Operational Environment Model," *Understanding the Operational Environment*, Briefing 14 May 2010.

NOEM is a strategic analysis / assessment tool that provides researchers, analysts, and decision makers with a platform to gain insight into complex interactions between a populace and their environment (security, economic, and social). Using existing data, it can produce baselines and forecast conditions. These inputs and derived datasets, it can be used to identify and simulate potential courses of action, when and where to invest in an unstable country or region.

NOEM models the operational environment, which encompasses the interconnectedness between the environment and the people. NOEM combines social behavior and operational theory (i.e. Stability Operations Theory) with researched leveraged from AFIT thesis and select SME's to create simulation modules. When possible, NOEM builds upon existing theories, such as greed and greviance, and related platforms, such as MASON.

Analysis

The NOEM major analysis components can be broken out in to three distinct capabilities.

1. "Model Development Environment" creates models through adapting to new regions/states and adding new modules and theories.

2. "Baseline Forecaster" generates forecasts based upon historical or current data inputs.

3. "Experiment Manager" simulates potential impacts of different "what if" scenarios/proposed courses of action.[14]

[14] AFRL *The National Operational Environment Model,* "Understanding the Operational Environment, Briefing 14 May 2010 by John Salerno.

Outputs

The basic components of NOEM are packaged into an open source suite of capabilities that are free and available to DoD researchers, analysts, and decision makers. Users can conduct simulations through modifying particular variables of interest to generate exportable graphs and charts.

Architecture

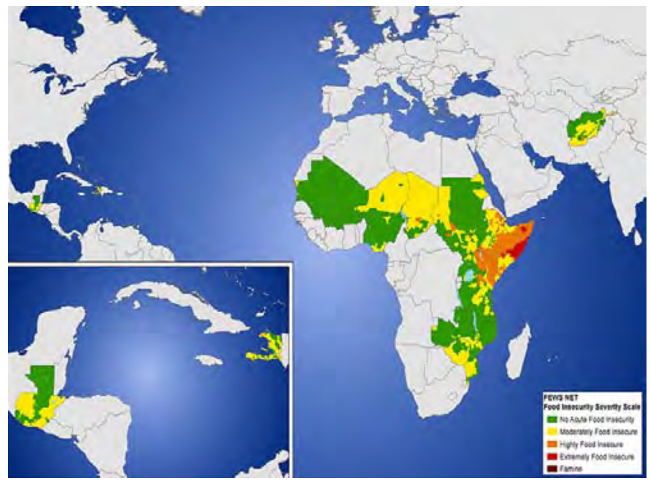
NOEM is run on a Java enabled, web-based software package with an intuitive user interface. Updated software releases are available through an USAF intranet NOEM website. The current software release is v0.7.2. The website also provides user's guides and software help. Use of the NOEM does not require desktop installation.

FAMINE EARLY WARNING SYSTEMS NETWORK

Developer	USAID
Analysis type	Data synthesis and analysis
Purpose	Identify potential threats to food security
Used by	USAID and international, regional, and national agencies

Data

The Famine Early Warning Systems Network (FEWS-NET) monitors food security issues by tracking data in the following categories:



- *Agro-climatic.* Satellite imagery of vegetation and weather forecasts.
- *Markets and trade.* Prices on public commodity markets.
- *Livelihoods.* Household vulnerability and ability to cope.
- *Remote monitoring.* Key food security indicators provided by FEWS-NET partners in monitored countries.

Analysis

FEWS-NET uses the Disaster Risk Reduction framework for food security analysis and early warning. This framework synthesizes two aspects of food security: household vulnerability to hazards and the risk of food insecurity. The following equation expresses this relationship:

RISK = f(Hazard, Vulnerability/Coping Capacity).

Both the vulnerability and coping capacity terms derive from the Household Economy Approach (HEA). HEA uses livelihoods data, organized by geographical area and broken down into wealth groups. The “hazard” information is derived from agro-climatic monitoring and market data.

Outputs

FEWS-NET has a range of outputs:

- Short-term food security projections (3 months)
- Medium-term food security projections (6 months)
- In-depth analyses of specific food crises
- Livelihood and market analyses
- Weather hazard analyses
- Alerts of critical situations.

The tool makes geospatial projections at the subnational level. Maps of FEWS-NET projections, as well as all analyses, are available. USAID and other FEWS-NET partners use the tool to identify high-risk areas and plan relief efforts.

Architecture

FEWS-NET is a public, web-based tool. The website displays all outputs, including maps and in-depth analyses. The most complicated part of the architecture is data gathering and synthesis. The tool accesses different sources at different frequencies, and the data take many forms (tabular, geospatial, and satellite imagery). Data used by FEWS-NET are available through the FEWS-NET data portal at earlywarning.usgs.gov/fews/.

The FEWS-NET calculation method is not publically available and therefore could not be leveraged by another tool. FEWS-NET is mature and is in active use by USAID.[15]

[15] USAID, Famine Early Warning System Network, http://www.fews.net/Pages/default.aspx, accessed April 18, 2011.

INTEGRATED CRISIS EARLY WARNING SYSTEM

Developer	Lockheed Martin–Advanced Technologies Laboratories (LM-ATL) on behalf of Defense Advanced Research Projects Administration (DARPA)
Analysis type	Predictive modeling, synthesis of logistic regression, Bayesian statistics, geo-spatial networks, and agent based models
Purpose	Monitor, assess, and forecast crises to support decisions on how to allocate resources to manage them
Used by	Ongoing research effort of DARPA; goal is combatant command use

Data

LM-ATL synthesized a combination of predictive modeling techniques—logistic regression, geo-spatial networks, and agent-based models—to form the Integrated Crisis Early Warning System (ICEWS). These models used three primary data sources:

1. *Country data*. The models used macro-structural and event data such as regime type and gross domestic product per capita. The data, largely publicly available, were pulled from more than 16 sources.

2. *Event data*. LM-ATL used the TABARI (KEDS) open-source event data coding tool from the University of Kansas to collect more than 6.7 million news stories from 75+ sources in the Pacific Command (PACOM) Area of Responsibility (AOR), the largest such data collection and coding project to date. The TABARI system allows automated data collection and event coding. The system is open source but the data compiled by LM-ATL are not.

3. *SME interviews*. SME interviews were used "to develop detailed profiles of archetypal leaders and followers for government and non-governmental groups within each country."[16] The data resulting from SME interviews

[16] Sean P. O'Brien, "Crisis Early Warning and Decision Support: Contemporary Approaches and Thoughts on Future Research," *International Studies Review*, Vol. 12, No. 1, (December 2010).

are not publically available. They are highly specialized to each country and cannot be generalized.

Analysis

LM-ATL uses a “mixed-methods” approach to predictive modeling, which synthesizes both statistical methods (logistic regression and geo-spatial networks) and agent-based models. The statistical models provide correlations, while the agent-based model provides possible causal mechanisms. Bayesian techniques aggregate all forecasts to a resultant forecast that is more accurate than each of the constituent parts.

Outputs

The LM-ATL ICEWS model predicts the state of conflict for a given country, outputting a score of 1–4 (no conflict to war). Monthly, quarterly, and 2- to 3-year forecasts are given.

The accuracy of the ICEWS model was tested, using historic conflict data from the PACOM AOR in 2005–06. Based upon the information provided by the LM-ATL ICEWS team, the model exceeded the minimum accuracy performance metric of 80 percent for three conflict types: ethnic/religious violence, rebellion, and insurgency. It did not meet the accuracy metric for the domestic political crisis and international crisis conflict types, likely due to their characteristically low intensity.

ICEWS is designed to provide military commanders with near-real-time forecasts or answers to three crucial questions:

1. “Which countries in a commander’s AOR are likely to become more or less unstable in the near-, mid-, and long-term?”
2. “What are the factors that are driving instability?”
3. “Given the array of national security resources across the entire DIME spectrum, what combinations of strategies, tactics, and resources are likely to have the greatest positive impact on mitigating the instability?”[17]

Architecture

The LM-ATL ICEWS model is built upon the ADAMS model integration framework, which comprises data services modules (data retrieval and storage), individual model modules, and a model synthesis module. This architecture allows the rapid integration of new models into the system. The model semi-autonomously retrieves data from the various sources. It is built on the Dynamic

[17] Ibid.

Information Architecture System (DIAS) framework developed by Argonne National Labs. Neither the LM-ATL model nor the DIAS framework is open source.[18]

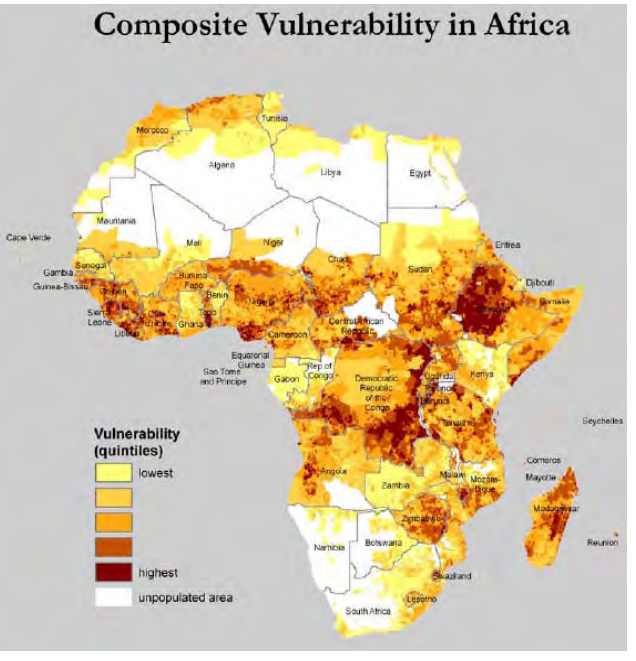
[18] Brian Kettler, "Mixed Methods Stability Forecasting and Mitigation for the DARPA ICEWS Program," (presentation, Third International Conference on Computational Cultural Dynamics, Washington, DC, December 7–8, 2009).

Climate Change and African Political Stability Program

Developer	University of Texas, Austin (funded by DoD's Minerva Initiative)
Analysis type	Geospatial analysis
Purpose	Understand how climate change and vulnerability to natural hazards intersect with demographic, social, and political sources of weakness
Used by	Researchers, policy community, journalists, and NGOs

Data

The Climate Change and African Political Stability Program (CCAPS) aims to assess how climate change could make African countries more vulnerable to humanitarian disasters and conflict, and how this could in turn affect African political stability and US security interests. The data focus is on existing national and subnational indicator variables associated with four main aspects of vulnerability:



1. Climate related hazard exposure
2. Household and community resilience
3. Governance and political violence
4. Population density.

Analysis

The CCAPS combines existing data on physical, socioeconomic, and political insecurities in Africa to develop a holistic model of vulnerability. The analysis uses Microsoft Excel workbooks to compile, initially process, and aggregate indicator data, which are then imported into a geographic information system (GIS) to map each aspect of vulnerability. The GIS overlays these maps to locate the confluence of the various aspects of vulnerability.

Outputs

Maps that reveal the locations of elevated levels of vulnerability to climate change and other risks in Africa.

Architecture

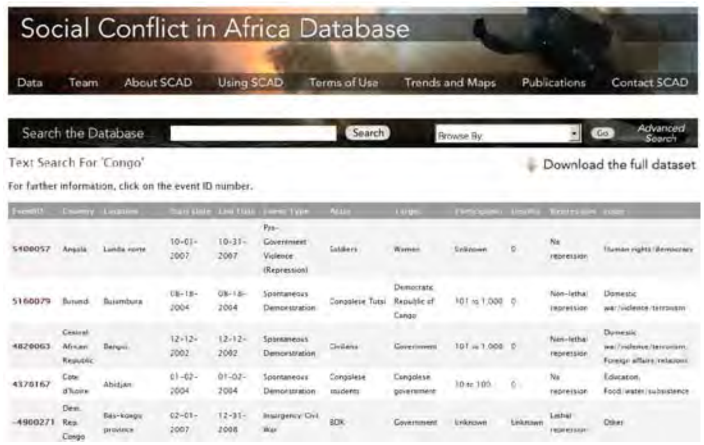
The analysis uses a GIS to combine indicator data from Microsoft Excel databases with other geo-referenced data.[19]

[19] J. Busby et al., *Locating Climate Insecurity: Where Are the most Vulnerable Places in Africa?* http://ccaps.strausscenter.org/system/ research_items/pdfs/ 19/original.pdf?1286296660, accessed August 2010.

Social Conflict in Africa Database

Developer	University of North Texas and University of Texas at Austin (funded by the Department of Defense's (DoD's) Minerva Initiative)
Analysis type	Data collection and geo-referencing
Purpose	To systematically detail social and political unrest events in Africa
Used by	Researchers, policy community, journalists, and non-governmental organizations (NGOs)

Data



The Social Conflict in Africa Database (SCAD) tracks more than 7,200 social and political unrest events from 1990 until 2010 for African countries with populations of more than 1 million people. For each event, the SCAD records information on the location, timing, and magnitude of conflict events. It also contains data on the event type, actors and targets involved, number of participants and fatalities, use of government repression, and issues of contention. The data sources include the Associated Press and Agence France Presse news wires.

Analysis

SCAD researchers review and compile information on African riots, strikes, protests, coups, and communal violence from global news wires. Each event receives a geo-reference tag to aid in mapping purposes.

Outputs

A database that tracks various forms of social and political conflict not covered in traditional datasets on armed conflict in Africa.

Architecture

The SCAD uses a web database software package that allows users to filter the database for a country, event, issue, start or end date, or key term search.[20]

[20] C. Hendrix and I. Salehyan, *Social Conflict in Africa Database (SCAD)*, http://www.ccaps.strausscenter.org/scad/conflicts, accessed April 19, 2011.

Appendix H
References

Army Environmental Policy Institute, *Environmental Factors in Forecasting State Fragility*, June 30, 2010, www.aepi.army.mil/.

Brian Kettler, "Mixed Methods Stability Forecasting and Mitigation for the DARPA ICEWS Program," (presentation, Third International Conference on Computational Cultural Dynamics, Washington, DC, December 7–8, 2009).

Bruce Berg, *Qualitative Research Methods for the Social Sciences*, sixth edition (Boston, MA: Pearson, 2006).

C. Hendrix and I. Salehyan, *Social Conflict in Africa Database (SCAD)*, http://www.ccaps.strausscenter.org/scad/conflicts, accessed April 19, 2011.

Carolyn Pumphrey, ed., *Global Climate Change National Security Implications* (Carlisle Barracks, PA: US Army War College, Strategic Studies Institute, 2008), www.strategicstudiesinstitute.army.mil/pubs/display.cfm?pubID=862.

Chairman, Joint Chiefs of Staff, *2011 National Military Strategy*, www.jcs.mil/content/files/2011-02/020811084800_2011_NMS_-_08_FEB_2011.pdf.

Chetan Agarwal, et. al., *A review and assessment of land-use change models: dynamics of space, time, and human choice*, General Technical Report NE-297, US Department of Agriculture, 2008, www.nrs.fs.fed.us/pubs/gtr/gtr_ne297.pdf.

Clionadh Raleigh, "Scales of Conflict Research," International Studies Association Convention, Montreal, March 16, 2011.

CNA Corporation, National Security and the Threat of Climate Change, 2007

Council on Environmental Quality, *Progress Report of the Interagency Climate Change Adaptation Task Force*, National Oceanic and Atmospheric Administration, Office of Science and Technology Policy, March 16, 2010, www.whitehouse.gov/sites/default/files/microsites/ceq/20100315-interagency-adaptation-progress-report.pdf.

David Satterthwaite et. al, *Adapting to climate change in urban areas. The possibilities and constraints in low and middle income nations* (International Institute for Environment and Development, 2007).

Dennis C. Blair, Annual Threat Assessment of the US Intelligence Community for the Senate Select Committee on Intelligence, February 2, 2010, intelligence.senate.gov/090212/blair.pdf.

Department of Defense (DoD) Instruction 3000.5, Stability Operations, September 16, 2009, www.dtic.mil/whs/directives/corres/pdf/300005p.pdf.

Department of the Army, 2011 Army Posture Statement, March 2011.

DoD, *2008 United States National Defense Strategy*, 2008, www.defenselink.mil/news/2008%20National%20Defense%20Strategy.pdf.

DoD, *Dictionary of Military and Associated Terms*, Joint Publication 1-02, November 8, 2010 (as amended through May 15, 2011), www.dtic.mil/doctrine/new_pubs/jp1_02.pdf.

Edward Miguel, Shanker Satyanath, and Ernest Sergenti, "Economic Shocks and Civil Conflict: An Instrumental Variables Approach, *Journal of Political Economy*, Vol. 112, No. 4, 2004.

Halvard Buhaug, Niles Petter Gleditsch, and Ole Magnus Theisen, *Implications of Climate Change for Armed Conflict* (Washington, DC: World Bank Group, Social Development Department, 2008, siteresources.worldbank.org/INTRANETSOCIALDEVELOPMENT/Resources/SDCCWorkingPaper_Conflict.pdf.

Headquarters Department of the Army, Field Manual 3-07, *Stability Operations*, October 6, 2008.

J. Busby et. al., *Locating Climate Insecurity: Where Are the most Vulnerable Places in Africa?* http://ccaps.strausscenter.org/system/research_items/pdfs/19/original.pdf?1286296660, accessed August 2010.

Jack Goldstone, *Special Report: Using Quantitative and Qualitative Models to Forecast Instability* (Washington, DC: US Institute of Peace, 2008).

Javier Fabra Mata (German Development Institute) and Sebastian Ziaja (United Nations Development Programme), Users' Guide on Measuring Fragility, www.carleton.ca/cifp/app/serve.php/1245.pdf.

John Agoglia, Michael Dziedzic, and Barbara Sotirin, *Measuring Progress in Conflict Environments (MPICE): A Metrics Framework* (US Institute of Peace Press, 2010).

Kalev Leetaru. The *GlobalNet Project-Future Directions.* (National Center for Supercomputing Applications (NCSA), University of Illinois, 2011).

Kalev Leetaru. *The NCSA GlobalNet Project and DARPA's ICEWS Initiative: A Comparison.* (NCSA, University of Illinois, 2011).

Karen O'Brien, et al., *Disaster Risk Reduction, Climate Change Adaptation and Human Security* (Oslo, Norway: University of Oslo, 2008), ISSN: 1504–5749.

Liverman et. al., ed., Committee on the Human Dimensions of Global Change, National Research Council, *People and Pixels: Linking Remote Sensing and Social Science* (Washington, DC: National Academy Press, 1998).

M. Abdollahian et. al., *Senturion—A Predictive Political Simulation Model*, Center for Technology and National Security Policy, July 2006.

Monty G. Marshall, *Political Instability Task Force Fact Sheet* (Arlington, VA: George Mason University, School of Public Policy, Center for Global Policy, 2009), globalpolicy.gmu.edu/pitf/.

National Academy of Sciences, *National Security Implications of Climate Change for U.S. Naval Forces*, 2011, www.nap.edu/catalog/12914.html.

National Intelligence Council, *Global Trends 2025: A Transformed World*, 2008, www.dni.gov/nic/PDF_2025/2025_Global_Trends_Final_Report.pdf.

National Security Council, National Security Presidential Directive 44, Management of Interagency Efforts Concerning Reconstruction and Stabilization, December 7, 2005.

Robert H. Bates, et. al., Political Instability Task Force Report: Phase IV Findings (McLean, VA: Science Applications International Corporation, 2003), globalpolicy.gmu.edu/pitf/.

Robert M. Gates, Remarks at US Global Leadership Campaign Tribute Dinner, Washington, DC, July 15, 2008.

Rymm J. Parsons, *Taking Up the Security Challenge of Climate Change* (US Army, Strategic Studies Institute, August 2009), www.strategicstudiesinstitute.army.mil/pubs/display.cfm?PubID=932.

S. Binkley, "Forecast and Analysis of Complex Threats III: Condensed Slides for Army Environmental Policy Institute (AEPI)," (briefing, December 2010).

Stark et. al., *Climate Change, Adaptation, and Conflict: A Preliminary Review of the Issues*, Conflict Management and Mitigation Discussion Paper No. 1, US Agency for International Development (USAID), October 2009.

Sean P. O'Brien, "Crisis Early Warning and Decision Support: Contemporary Approaches and Thoughts on Future Research," *International Studies Review*, Vol. 12, No. 1, (December 2010).

SERENGETI, "A Unique Architecture: A Unique Organization," *Defense Intelligence Agency Communiqué*, 2010.

Susan Rice and Stewart Patrick, *Index of State Weakness in the Developing World* (Washington, DC: The Brookings Institution, 2008), www.brookings.edu/reports/2008/02_weak_states_index.aspx.

The Interagency Conflict Assessment Framework: The USG's Interagency Tool for Conflict Assessment, www.mors.org/UserFiles/file/2010%20Interagency/Irmer%20presentation%20REDUC%20(2).pdf.

UN Intergovernmental Panel on Climate Change (IPCC), *Climate change 2007*: *The physical science basis,* Report of Working Group I to the Fourth Assessment Report of the IPCC (New York: Cambridge University Press, 2007).

US Department of State, *Quadrennial Diplomacy and Development Review*, 2010, www.state.gov/s/dmr/qddr/.

United Nations Human Settlements Programme (UN HABITAT), "Cities and climate change adaptation," paper presented at UN HABITAT Donors Meeting, Seville, 2008.

United Nations Statistics Division, Software Options for Operational Geographic Information System in Professional Environments, Workshop on International Standards, Contemporary Technologies and Regional Cooperation, 04-04 February 2008.

USAID, *Climate Change, Adaptation, and Conflict: A Preliminary Review of the Issues*, October 2009, www.usaid.gov/our_work/cross-/cutting_programs/conflict/publications/docs/CMMDiscussionPaper1ClimateChangeAdaptationandConflict.pdf.

USAID, *Conflict, Fragility, and the Environment: A USAID/DCHA/CMM Experts' Workshop: Summary Report*, May 2011.

USAID, Famine Early Warning System Network, http://www.fews.net/Pages/default.aspx, accessed April 18, 2011.

US Joint Forces Command. *Joint Operating Environment (JOE)*, 2010, www.jfcom.mil/newslink/storyarchive/2010/JOE_2010_o.pdf.

Appendix I

Glossary

Adaptation. The ability to make adjustments that help a society to survive and thrive within changing conditions. It involves changes to, or development of, characteristics that enable and entity to better suit new conditions and reduces vulnerability.

Conflict. An armed struggle within a nation or between nations as well as includes nonviolent social tension between internal groups because of the relevance to fragility and vulnerability.

Domain. In the context of human decision making, domain is defined as the widest social organization incorporated in a dataset, for example, a nation or region.

Exclusive economic zone (EEZ). The marine zone where coastal nations have jurisdiction over economic and resource management. The EEZ stretches from the seaward edge of a nation's territory to 200 nautical miles from its coast.

Fragility. For this report, the Army Field Manual (FM) 3-07, definition for a fragile state is the functional definition for this report with the caveat that it is based on the human security construct associated with social and economical vulnerability. It is defined as a "Country that suffers from institutional weaknesses serious enough to threaten the stability of the central government … aris[ing] from several root causes, including ineffective governance, criminalization of the state, economic failure, external aggression, and internal strife due to disenfranchisement of large sections of the population. Fragile states frequently fail to achieve any momentum toward development [and can] generate tremendous human suffering, create regional security challenges, and collapse into wide, ungoverned areas that can become safe havens for terrorists and criminal organizations."

Geospatial data. Data produced through joining data elements with geographic map data, most commonly producing either raster or vector data sets.

Hobbesian conditions. Explained by philosopher Thomas Hobbes in his book, *Leviathan,* to describe the natural state of mankind, without a political community. "In such condition, there is no place for industry; because the fruit thereof is uncertain: and consequently no culture of the earth; no navigation, nor use of the commodities that may be imported by sea; no commodious building; no instruments of moving, and removing, such things as require much force; no knowledge of the face of the earth; no account of time; no arts; no letters; no society; and which is worst of all, continual fear, and danger of violent death; and the life of man, solitary, poor, nasty, brutish, and short."

Instability. The risk of a destabilizing event as outlined by the US Agency for International Development, particularly in light of the nature of instability experiences during the 2011 "Arab Spring."

Natural security. Security of natural resources. Natural security ultimately means sufficient, reliable, affordable, and sustainable supplies of natural resources for the modern global economy.

Raster data. Geospatial data format comprised of a grid of equal-sized cells, with each cell representing a specific value.

Resilience. The capacity to absorb, respond to, and recover from a natural or manmade disruptive event. It reflects the ability to cope with a disturbance and retain essential structures and functions.

Resolution. The spatial or temporal scale used to present a dataset.

Scale. As defined in Argawal et. al. (2002), scale in a geographical context is defined as "the ration of length of a unity distance on a map and the length of that same unit of distance on the ground in reality."In a social science context, scale is defined as the full extent covered in a study or analysis (i.e., small-scale study vs. large-scale study).

Stability operations. As defined by the Army FM 3-07, "[stability operations encompass] various military missions, tasks, and activities conducted outside the United States in coordination with other instruments of national power to maintain or reestablish a safe and secure environment, provide essential governmental services, emergency infrastructure reconstruction, and humanitarian relief."

Vector data. Geospatial data format that uses polygons, lines, and points to represent areas and features in space.

SECTOR DEFINITIONS

Agriculture. Production of crops for food, fiber, and energy, and its management and distribution.

Forestry. Management (or lack thereof) of trees, forests, timber, and associated habitat.

Water. Treatment, management and/or distribution of ground or surface water for human consumption and economic sector uses.

Energy. Processing of renewable and non-renewable natural resources to produce heat, work, fuel, and/or electricity.

Fisheries. Human exploitation, management, and/or protection of fresh or salt water fish stocks.

Waste. Collection, treatment and management of solid and liquid wastes, domestic, municipal, industrial, and agricultural.

Mining and materials. Mining of raw materials, refinement, recovery, and reuse of energy carriers or materials.

Health. Public health organizations and health service providers.

Natural disaster response. Preparation for, response to, and recovery from natural disasters.

NATURAL RESOURCE DEFINITIONS

Reclaimed water. Tertiary treated wastewater that meets the respective drinking, agriculture, and industrial water standards, depending upon intended use.

Groundwater. Freshwater found in subsurface aquifers.

Oceans. Saltwater bodies of water.

Surface water bodies. Fresh water rivers, lakes, and streams.

Fish. Aquatic species found in fresh, brackish, or salt water, generally suitable for human consumption.

Non-renewable resources. Finite resources that can be depleted or used and cannot be renewed on a human timescale, such as a lifetime.

Non-fuel minerals. Non-energy minerals and materials used in industrial capital, construction, and consumer products that can often be recycled (but often are not or are recycled in ways that may not alleviate security concerns.)

Land. The area or space of terrain/property, not exclusively linked with the quality of the soil.

Soil. Stable mixtures of organic and mineral materials that can support the growth of crops, forests, etc.

Forests. Trees, timber, and woody plant dominant habitats.

Organic waste. Discarded organic matter and materials.

Air. Atmospheric gas mixture that supports respiration. Generally focused on local and tropospheric qualities.

Appendix J
Abbreviations

3Ds	diplomacy, development, and defense
ABM	agent-based model
ACLED	Armed Conflict Location and Event Dataset
AEPI	Army Environmental Policy Institute
AFRICOM	Africa Command
AFRL	Air Force Research Laboratory
AGC	Army Geospatial Center
AOR	Area of Responsibility
APAN	All Partners Access Network
APSI	Army Peacekeeping and Stability Initiative
ASA(IE&E)	Assistant Secretary of the Army for Installations, Energy and Environment
BBC	British Broadcasting Corporation
CAA	Center for Army Analysis
CASI	Center for the Advancement of Sustainability Innovations
CCAPS	Climate Change and African Political Stability
CCREL	Cold Regions Laboratory
CENTCOM	Central Command
CERL	Construction Engineering Research Laboratory
CESU	Cooperative Ecosystem Studies Unit
CIA	Central Intelligence Agency
CIDCM	Center for International Development and Conflict Management
CIESIN	Center for International Earth Science Information Network
CMM	Conflict Management and Mitigation
COCOM	combatant command
COW	Correlates of War
CSCW	Centre for the Study of Civil War

CSV	comma-separated values
DARPA	Defense Advanced Research Projects Administration
DIA	Defense Intelligence Agency
DIAS	Dynamic Information Architecture System
DIE	German Development Institute
DIME	diplomatic, information, military, and economic
DoD	Department of Defense
DoDD	Department of Defense Directive
DoDI	Department of Defense Instruction
DSCA	Defense Security Cooperation Agency
DTRA	Defense Threat Reduction Agency
EEZ	exclusive economic zone
EM	electromagnetic
EMM	Europe Media Monitor
EoI	event of interest
EOS	Earth Observing System
ERAP	Emergency Response Asset Picture
ERDC	Engineering Research and Development Center
ESRI	Environmental Systems Research Institute
EU	European Union
EUCOM	European Command
FACT	Forecast and Analysis of Complex Threats
FEWS-NET	Famine Early Warning Systems Network
FIRST	Facts on International Relations and Security Trends
FfP	Fund for Peace
FM	Field Manual
FOUO	for official use only
GDP	gross domestic product
GEO	Group on Earth Observations
GEOSS	Global Earth Observation System of Systems
GHG	greenhouse gas
GIS	geographic information system

GMES	Global Monitoring for Environment and Security
GMU	George Mason University
GOS	Geospatial One-Stop
GTD	Global Terrorism Database
HADR	humanitarian assistance disaster recovery
HEA	Household Economy Approach
HQDA	Headquarters, Department of the Army
IAWG	Intra-Army Working Group
ICAF	Interagency Conflict Assessment Framework
ICEWS	Integrated Crisis Early Warning System
INSPIRE	Infrastructure for Spatial Information in the European Community
IPCC	Intergovernmental Panel on Climate Change
ISN	International Relations and Security Network
JOE	*Joint Operating Environment*
LM-ATL	Lockheed Martin-Advanced Technologies Laboratories
mil-to-mil	military-to-military
MPICE	Measuring Progress in Conflict Environments
NASA	National Aeronautics and Space Administration
NCSA	National Center for Supercomputing Applications
NCTC	National Counter Terrorism Center
NGA	National Geospatial-Intelligence Agency
NGO	non-governmental organization
NIC	National Intelligence Council
NIE	national intelligence estimate
NMS	*National Military Strategy*
NOAA	National Oceanic and Atmospheric Administration
NOEM	National Operational Environment Model
NSPD	National Security Presidential Directive
NSS	*National Security Strategy*
OECD	Organisation for Economic Co-operation and Development
OMB	Office of Management and Budget
PACOM	Pacific Command

POC	point of contact
PPNRA	Proactive Peacebuilding with Natural Resource Assets
PRIO	Peace Research Institute Oslo
QDDR	*Quadrennial Diplomacy and Development Review*
QDR	Quadrennial Defense Review
SCAD	Social Conflict in Africa Database
SEDAC	Socioeconomic Data and Applications Center
SIPRI	Stockholm International Peace Research Institute
SME	subject matter expert
SOA	service-oriented architecture
SOUTHCOM	Southern Command
SPEED	Social, Political, and Economic Event Database
SSTR	stability, security, transition, and reconstruction
SWB	summary world broadcasts
UCDP	Uppsala Conflict Data Program
UN	United Nations
UN HABITAT	United Nations Human Settlements Programme
UNDP	United Nation Development Programme
UNEP	United Nations Environment Programme
USACAPOC(A)	US Army Civil Affairs and Psychological Operations Command (Airborne)
USACE	US Army Corps of Engineers
USAID	US Agency for International Development
USD	Under Secretary of Defense
USD(P)	Office of the Under Secretary of Defense for Policy
USDA	US Department of Agriculture
USJFC	US Joint Forces Command
WITS	World Incident Tracking System