

BIG DATA for RESILIENCE

STORYBOOK

Experiences
integrating Big Data
into resilience
programming

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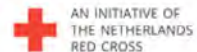
Big Data for Resilience Storybook:

Experiences
integrating
Big Data into
resilience
programming

An initiative of:



In collaboration with:



European Union
Civil Protection and
Humanitarian Aid

Table of Abbreviations

AWI	Advanced Weather Information
AWS	Amazon Web Services
CAPMON	Canadian Atmospheric Pollutants Monitoring Network
CCAFS	Climate Change, Agriculture and Food Security
CRA	Country Risk Assessment
DFID	Department for International Development
DRC	Democratic Republic of the Congo
DRR	Disaster Risk Reduction
EbA	Ecosystem-based adaptation
FAIR	Findable, accessible, interoperable, and reusable
FAO	Food & Agriculture Organisation
GPSDD	Global Partnership for Sustainable Development Data
HOT	Humanitarian OpenStreetMap Team
ICT	Information and communication technology
IISD	International Institute for Sustainable Development
LTER	Long-term ecological research
M&E	Monitoring and Evaluation
NAP	National Adaptation Plan
OCHA	Office for the Coordination of Humanitarian Affairs
OSM	OpenStreetMap
PDNA	Post Disaster Needs Assessment
VAMPIRE	Vulnerability Analysis Monitoring Platform for the Impact of Regional Events
VCA	Vulnerability and Capacity Assessment
WFP	World Food Programme

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Introduction

The growth of social networks and the accelerated pace of modern communications have placed a renewed emphasis on global interconnectedness and scale in the international development field. These notions are particularly relevant to understanding the complex nature of vulnerability, as well as the ability of systems—e.g., individuals, households, communities or countries—to cope with, adapt to, and potentially transform in the face of shocks and stressors, i.e., “resilience.”

The information and communication technology (ICT) revolution has been accompanied by an increasing emergence of very large datasets. According to a recent article published in *The Economist*,¹ data is to this century what oil was to the last one: a driver of growth and change.

Big Data has emerged as a multifaceted phenomenon that is dramatically changing data collection and processing.² The term is commonly used to refer to unprecedented volumes of data that are so large or complex that traditional data processing applications are inadequate to deal with them, but has evolved to encompass more than

that. Later definitions highlight the “four Vs” of Big Data: volume, velocity, variety³ and veracity, which have allowed new approaches to predictive analytics, user behaviour analytics, and other methods to visualize and to extract value from data. More recently, the Data-Pop Alliance defined Big Data as follows:

a new socio-technological phenomenon resulting from the emergence and development of an ecosystem made up of the new kinds of data “crumbs” about human behaviours and beliefs generated and collected by digital devices and services, ever more powerful computing power and analytics tools, and a vibrant community of actors in this field.⁴

While there is a growing body of literature and practical experiences at the intersection of Big Data and development⁵ particularly in the field of humanitarian emergencies⁶ and the Sustainable Development Goals,⁷ there is a critical knowledge gap regarding the use, potential and challenges associated with the use of Big Data in resilience programming.

Big Data is a relatively new topic in the resilience discourse, one that has not been rigorously explored or incorporated as part of resilience programming approaches. It offers a new angle for development practitioners to observe, analyze and use large-scale evidence related to the impacts of shocks and stressors over time, and to inform resilience-building processes. Its rapid development and adoption presents new challenges and opportunities for resilience programming, including questions regarding (but not limited to) measuring pathways of change across scales, integrating diverse stakeholders and learning from cross-scale dynamics in real and near-real time.

The massive amounts of data being collected both passively and opportunistically through technological tools and devices requires resilience practitioners to rethink key questions that arise from the design, implementation, monitoring and evaluation of projects, including the role of ethics, privacy and security, technology access, governance and sociocultural contexts in data collection and analysis.

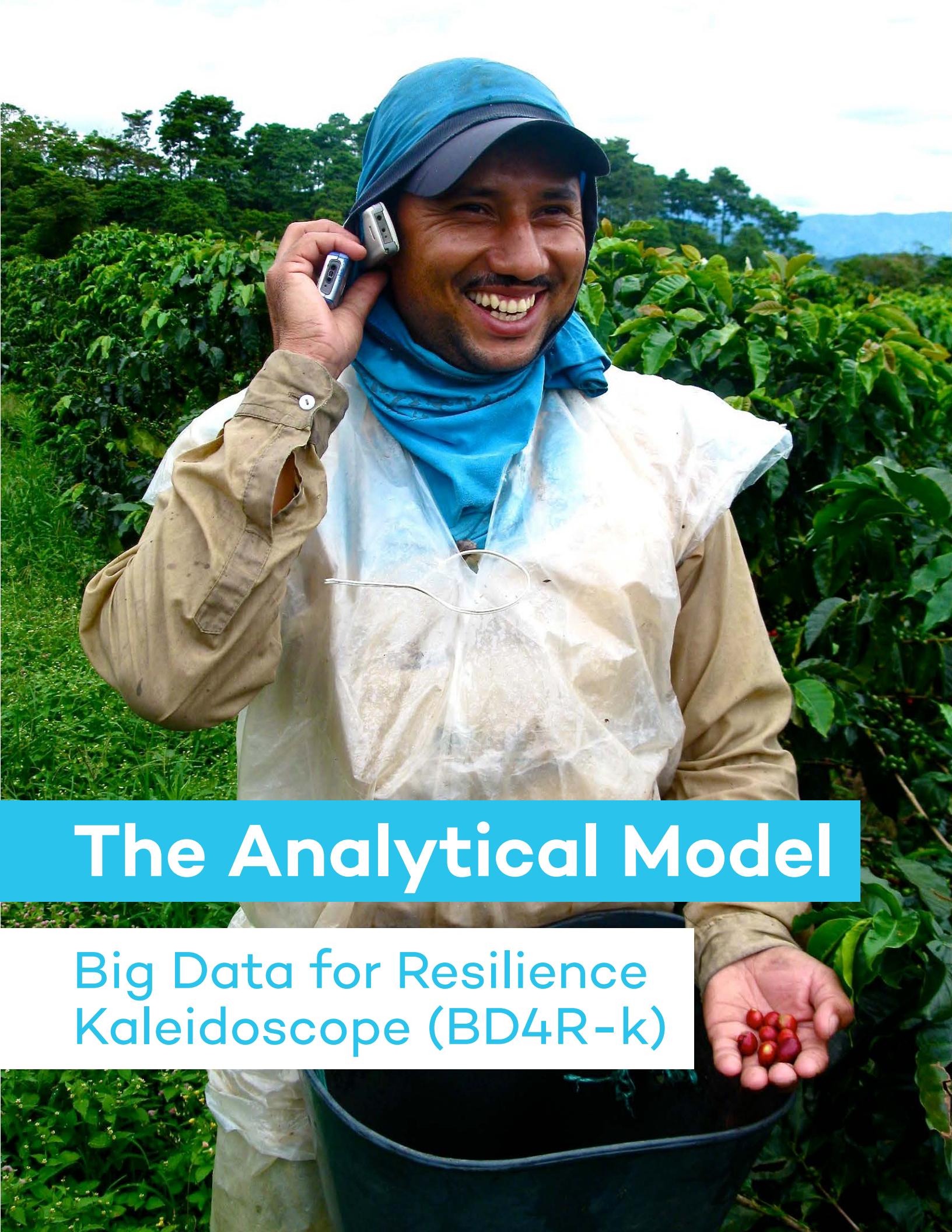
The main purpose of this “Storybook” is to help bridge the gap between Big Data and resilience programming through the experiences of seven international organizations: the UN Global Pulse, Conservation International, the Netherlands Red Cross, CGIAR, Mercy Corps, the Humanitarian OpenStreetMap Team, and the International Institute for Sustainable Development (IISD).

Ranging from resilience-building efforts in rural Malawi, Mongolia and Indonesia, an urban resilience project in Tanzania, and freshwater ecosystems resilience in Canada (among other regional and global initiatives) the wide range of experiences presented in this Storybook provide new insights about an increasingly relevant field of enquiry. These experiences reflect not only the complexity of humanitarian and development contexts, but also the opportunities offered by Big Data to strengthen the impact of resilience-building efforts.

Aimed at an audience of resilience and development practitioners, the publication seeks to foster new dialogue about the role of Big Data as part of resilience programming in contexts affected by the impacts of shocks and stressors, and offers concrete, practice-based recommendations to leverage its potential and address its risks.

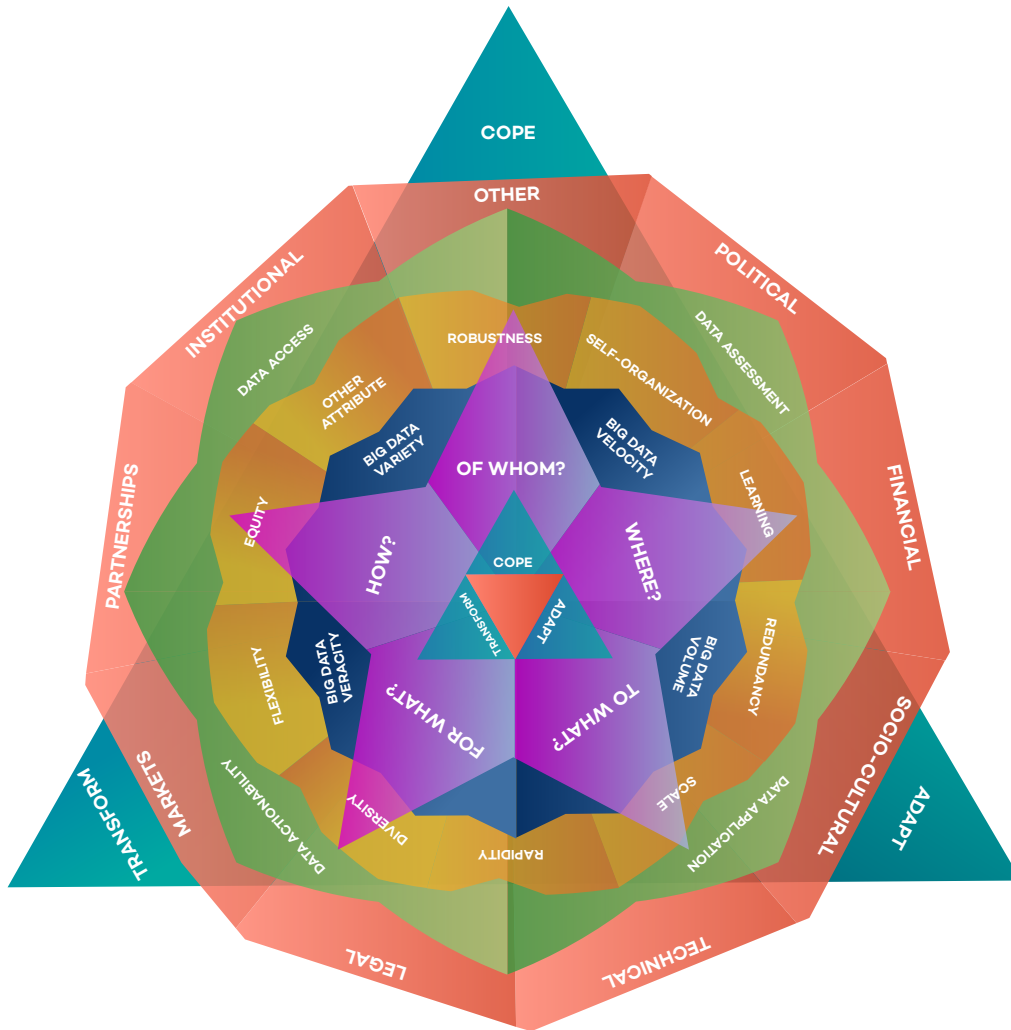
The structure of the eight cases featured in the Storybook is based on a new analytical model developed as part of this initiative—the Big Data for Resilience Kaleidoscope (BD4R-k). An overview of the model is provided in the following section.

The knowledge exchange that this publication seeks to foster is not simply about Big Data for Resilience. It is about *better* Big Data for Resilience. It is about what we still need to learn and to improve as resilience practitioners, as decision makers or as researchers in order to ensure that Big Data is effectively accessed, assessed, applied and used to improve the resilience of vulnerable populations and ecosystems to shocks and stressors.



The Analytical Model

Big Data for Resilience
Kaleidoscope (BD4R-k)



The Big Data for Resilience Kaleidoscope (BD4R-k) is a novel analytical model designed to help resilience practitioners and decision makers gain a more in-depth understanding of the role of Big Data in resilience-building processes, and to strengthen those processes through a more robust approach to data access, assessment and use.

The BD4R-k model was developed in response to the lack of a robust conceptual approach to identifying and deepening the understanding about the key components that influence Big Data’s role in resilience building, as well as to provide new insights about the role of data and knowledge generation in these processes.

The model provides a holistic perspective of the key factors that play a role in the use of Big Data for resilience. It helps to visualize the linkages that exist between Big Data and resilience, assess areas of strength and weakness, and to identify gaps and opportunities to strengthen resilience programming and impact.¹

¹ The BD4R-k builds on resilience conceptual approaches, including the Resilience Assessment Benchmarking and Impact Toolkit (RABIT) developed by the University of Manchester, England, and the Dynamic Resilience Wheel (DREW) developed by Lutheran World Relief (LWR).



BD4R-k Components

The BD4R-k contains the key factors that lie at the intersection of resilience and Big Data initiatives. These components are organized in six sections—each of them a distinct layer of the Big Data for resilience kaleidoscope. Each layer—as well as the interactions among all of them—is critical to understanding the linkages between Big Data and resilience building in complex development environments.

1

RESILIENCE CORE

At the heart of the BD4R-k, this section corresponds to the working definition of resilience: the ability of a vulnerable system to cope with, adapt, and potentially transform amid the impacts of shocks and stressors. Ultimately, the use of Big Data and its interactions with the other components of the Kaleidoscope, explained below, should contribute to strengthening these core capacities.

COPE

Coping capacity refers to the ability to absorb and mitigate the impacts of shocks. Examples include measures for risk awareness and prevention, as well as strategies to withstand and recover from the effects of shocks in the short term (e.g., access to savings, food stocks).

ADAPT

Adaptive capacity refers to the ability to adjust to the impacts of shocks and stressors, and to take advantage of opportunities that may emerge with change. Examples include livelihoods diversification, adoption of new production techniques, and collaboration with wider networks that enable change in the medium and/or long term.

TRANSFORM

Transformative capacity refers to the ability to achieve a new state through a combination of technological innovations, institutional reforms, behavioural shifts and cultural changes, among other factors. These are changes that normally take place over the long term.

RESILIENCE FOUNDATIONS

It provides the resilience context of the initiative, by addressing five key resilience questions: resilience where, of whom, to what, for what and how?.⁸

RESILIENCE WHERE?

Refers to the geographic setting where a project is implemented (e.g., urban, rural, mountainous, transboundary or coastal area). This question can also help in determining the scale of implementation (e.g., community, regional, national or international level).

RESILIENCE OF WHOM?

Refers to the identification of the system of focus of the project or initiative (e.g., individual, household, community, institution), as well as of specific project beneficiaries (e.g., men, women, boys and girls).

RESILIENCE TO WHAT?

Refers to the key shocks/stressors that affect the context of implementation, including the identification of their main impacts on the system of focus and on the project's beneficiaries (e.g., men, women, boys and girls)

RESILIENCE FOR WHAT?

Refers to the project's goal (e.g., development outcome that the initiative aims to achieve).

RESILIENCE HOW?

Refers to the mechanisms through which the project goes about building resilience. It includes the specific activities undertaken in order to strengthen resilience capacities (absorb, adapt, transform) of the system of focus/project beneficiaries. This question involves the identification of specific project activities that involve the use of Big Data to order to strengthen coping, adaptive and/or transformative capacities.

3

BIG DATA BASICS

This section identifies the 4 “Vs” or key characteristics of Big Data: volume, velocity, variety and veracity.⁹ When considered as part of a broader analytical context (that is, in relation to the resilience questions, the resilience attributes and the data impact chain, explained below) these characteristics allow a more in-depth understanding of Big Data’s role, potential and challenges in resilience building.

BIG DATA VOLUME

Refers to the estimated volume of the Big Data of the initiative (e.g., megabyte, gigabyte, terabyte, petabyte, exabyte).

BIG DATA VELOCITY

Refers to the estimated velocity of Big Data collection (e.g., batch, periodic, near-real time, real time).

BIG DATA VARIETY

Refers to the type of Big Data being collected (e.g., table, database, photo, web, audio, social media, mobile, unstructured).

BIG DATA VERACITY

Refers to the mechanisms in place to verify the veracity of the data, and to ensure its quality/authenticity.

4

BIG DATA 4 RESILIENCE: ATTRIBUTES

This section identifies a set of key attributes of resilient systems (robustness, self-organization, learning, redundancy, rapidity, scale, diversity, flexibility and equity)¹⁰, providing an opportunity to explore the contributions of Big Data toward each of them (positive as well as potentially negative, recognizing that the use of Big Data could also weaken certain attributes). These attributes are not exhaustive and complement each other.

ROBUSTNESS

Ability of the system to maintain its characteristics and continue to function despite the impact of shocks and stressors.

SELF-ORGANIZATION

Ability of the system to independently rearrange its functions and processes.

LEARNING

Ability of the system to gain or create knowledge and strengthen the skills and capacities of its members.

REDUNDANCY

Availability of additional resources that are substitutable and can be accessed by system stakeholders to respond to shocks and stressors.

RAPIDITY

Speed at which assets can be accessed or mobilized by the system stakeholders to achieve goals efficiently.

SCALE

Breadth of resources (e.g., at the regional, national or international levels) that a system can access to effectively overcome or adapt to the effects of shocks and stressors.



DIVERSITY

Ability of the system to explore and/or undertake different options, innovate and benefit from emerging opportunities.

FLEXIBILITY

Ability of the system to undertake different courses of actions with the resources at its disposal, including adaptable decision making.

EQUITY

Extent to which the system provides fair access to rights, resources and opportunities to its members (women and men), according to their respective needs.

OTHER ATTRIBUTES

...recognizing that those listed above are not exhaustive or exclusive, and that there may be other attributes that are relevant for the resilience of different systems.

5

BIG DATA 4 RESILIENCE: DATA IMPACT CHAIN

This section focuses on the value of Big Data and its role in the achievement of resilience outcomes. It presents the key stages needed for data to translate into action (i.e. data access, assessment, application to decision making and actionability), building on the components of the “information chain”:¹¹. By looking at the role of data from an “impact chain” perspective, the analysis moves beyond data availability to consider the capacity of resilience stakeholders to effectively access, understand, and use Big Data to inform pathways of change.

DATA ACCESS

Ability to access or retrieve data (unprocessed facts and figures) stored within a database or other repository.

DATA ASSESSMENT

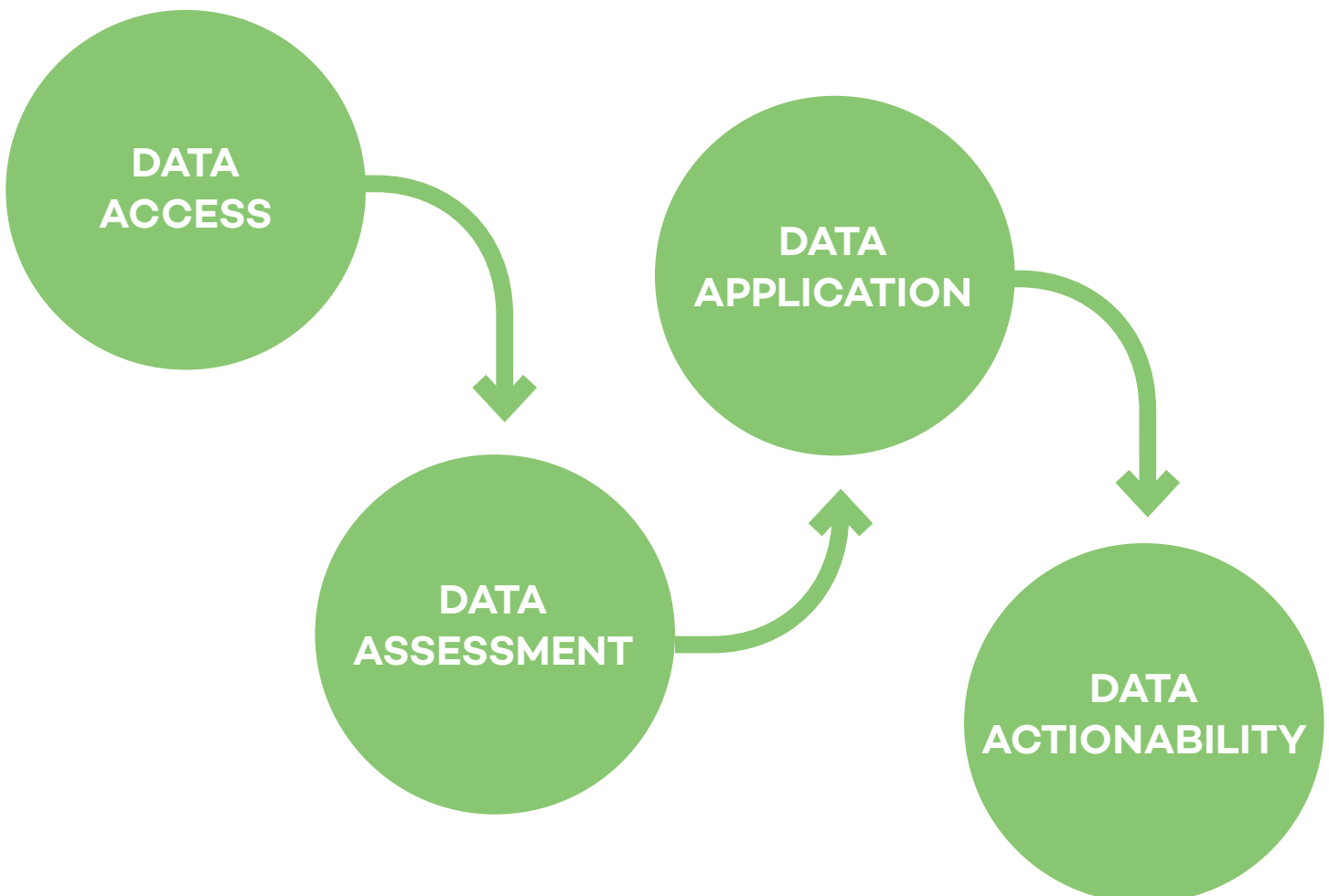
Ability to assess, visualize, analyze and understand the relevance of the data.

DATA APPLICATION

Ability to apply the information to a specific decision. This stage refers to the use of the information as part of the decision-making process.

DATA ACTIONABILITY

Ability to actually act upon that information, to contribute to the achievement of a development outcome. Actionability is the last stage of the data-impact cycle, as it refers to the enactment or actual implementation of the decisions taken based on the information.



6

BIG DATA 4 RESILIENCE: ENABLING ENVIRONMENT¹²

This section identifies key contextual factors that influence (by enabling or by limiting) the role of Big Data in resilience-building processes.

These factors help shape the specific impact and “uniqueness” of Big Data’s contribution to development.

POLITICAL FACTORS

(e.g., government support, policies, alignment with government strategies)

FINANCIAL FACTORS

(e.g., economic resources, access to credit/financing, sustainability)

SOCIOCULTURAL FACTORS

(e.g., engagement of local communities, knowledge and trust, motivation)

TECHNICAL FACTORS

(e.g., technical skills/ know-how, infrastructure and technological aspects)

INSTITUTIONAL FACTORS

(e.g., institutional strategies, credibility)

LEGAL FACTORS

(e.g., legal frameworks and regulations, privacy and security, ethical considerations)

MARKETS

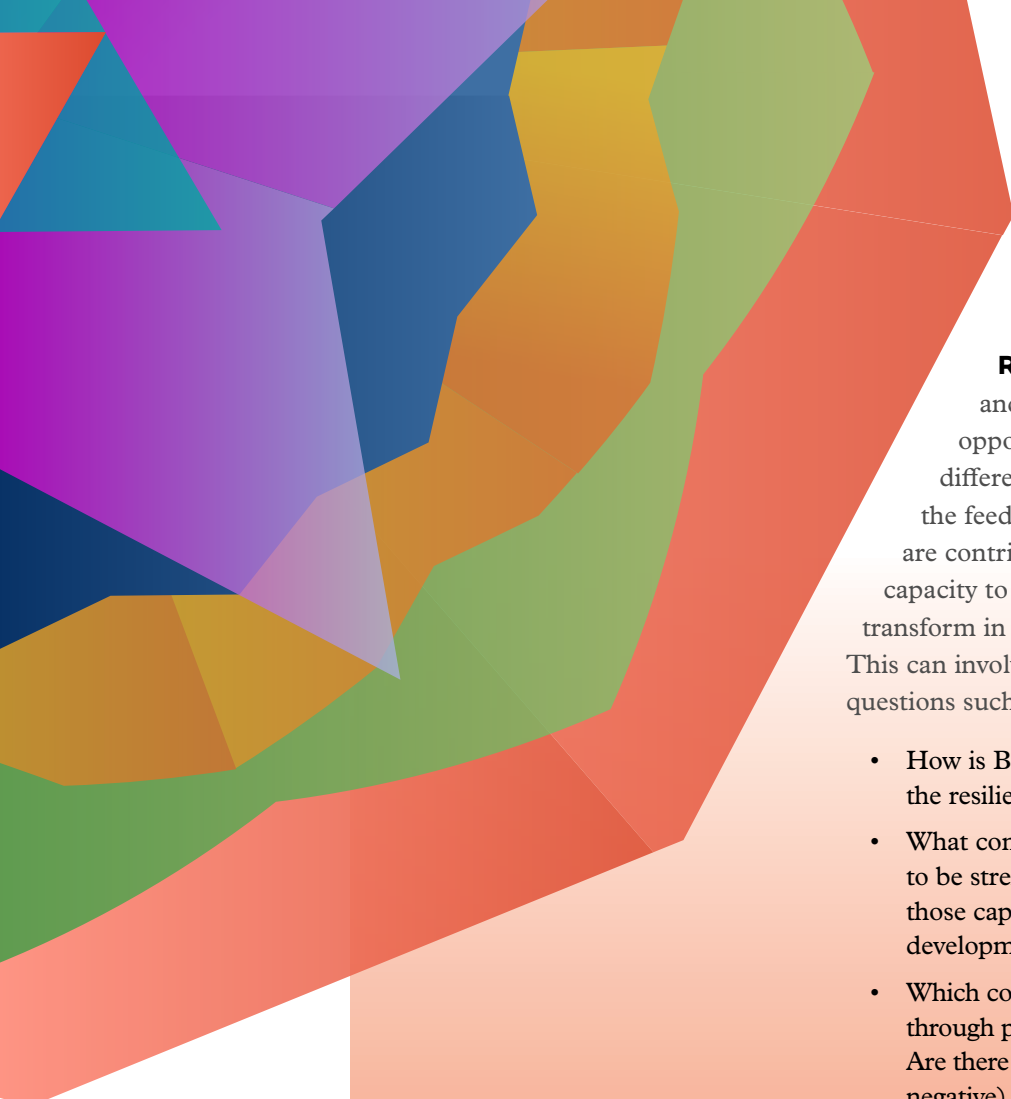
(e.g., supply/demand, transportation costs, prices)

PARTNERSHIPS

(e.g., partnerships with multisectoral stakeholders)

OTHER FACTORS

...recognizing that the factors included above are not exhaustive or exclusive, and that there may be other factors that enable or constrain Big Data’s role in different contexts.



The final, outer layer of the BD4R-k model is again the **RESILIENCE CORE** (cope, adapt and transform). It provides an opportunity to reflect on how the different components of the model, and the feedbacks and interactions among them, are contributing (or not) to build the system's capacity to cope with, adapt and potentially transform in the face of shocks and stressors. This can involve a more in-depth examination of questions such as:

- How is Big Data contributing to strengthen the resilience capacities of the system of focus?
- What components of the model would need to be strengthened in order to improve those capacities and achieve the desired development outcome of the project/initiative?
- Which components should be prioritized through programming/project implementation? Are there any unintended (positive and negative) effects from the use of Big Data?

Each of the experiences featured in this Storybook addresses the components of BD4R-k, providing a deeper, more systematic look into the factors at the intersection of Big Data and resilience.

The online version of the BD4R-k provides further insights into its components, dynamic features and its potential role in Big Data for resilience assessments.

An aerial photograph of a vast, forested landscape. The terrain is covered in dense green trees, with several large, irregularly shaped lakes scattered throughout. A winding river or stream flows through the forest. The sky is a pale, hazy blue, suggesting a bright but slightly overcast day. The overall scene is a natural, undisturbed ecosystem.

A Novel Take on Resilience Building

Big Data's Role in
Freshwater Ecosystems

An initiative of the International Institute for Sustainable Development
Experimental Lakes Area (IISD-ELA)

Deep in Canada’s boreal forests is a pristine network of 58 lakes and a team of scientists that have informed and shape global knowledge about the resilience of freshwater ecosystems to climate impacts. The International Institute for Sustainable Development’s Experimental Lakes Area (IISD-ELA) is a unique site that holds a long-term environmental dataset. With 50 years of physical and biological data, this data contributes to understanding local changes and helps inform a new generation of long-term ecosystem research.

Freshwater ecosystems like IISD-ELA are found in the headwaters of continental drainage basins: the source for streams and rivers that provide drinking water to millions of people. IISD-ELA is a natural laboratory, allowing scientists to use short-term lake manipulation experiments to understand human impacts and promote sustainable policies and management of Canada’s freshwater resources.

It is one of the world’s few facilities capable of conducting whole-ecosystem research on freshwater environments. In whole-ecosystem experiments, scientists can manipulate specific lake processes (e.g., a nutrient, a species of fish, a pollutant or contaminant), and use nearby un-manipulated lakes

as controls. This allows robust determination of impact effects of potential drivers of change, while accounting for the complexity of interactions and relationships in natural systems. Data collected through whole-ecosystem experiments can provide a unique, holistic view of the complexity of factors that play a role in building resilience to the impacts of climate change.

Scientific findings based on the long-term monitoring program have been crucial to identifying how lakes and the animals within the lakes react to subtle changes in climate over time, as well as to inform policy-making.

Resilience Snapshot

IISD-ELA & CORE RESILIENCE QUESTIONS

RESILIENCE WHERE?

Ontario, Canada

RESILIENCE OF WHAT?

Freshwater ecosystems

RESILIENCE OF WHAT?

Climate change impacts

RESILIENCE FOR WHAT PURPOSE?

Improved ability to manage freshwater systems in the context of climate change

RESILIENCE HOW?

It uses long-term data to strengthen the knowledge base about climatic impacts and temperature variations over time, in order to inform decisions that protect and increase the resilience of freshwater ecosystems.

Long-term Ecological Research, Big Data and Resilience

The IISD-ELA provides an ideal observatory for understanding the effects of climate change on boreal forests, wetlands and lakes from a long-term, whole-ecosystem perspective. Its long-term ecological research program (LTER), initiated in 1968, includes sub-programs that collect data at different spatial and temporal scales from several themes including meteorology, hydrology, limnology and fisheries.

The IISD-ELA operates a manned year-round meteorological station that collects standard weather data (e.g., air temperature, precipitation, barometric pressure, wind speed and direction, etc.) and additional parameters (e.g., sunlight intensity, precipitation chemistry, etc.).

The meteorological station is also part of the CAPMON (Canadian Atmospheric Pollutants Monitoring Network) that collects data on a suite of atmospheric pollutants, with data available from Environment Canada.

IISD-ELA's long-term monitoring dataset constitutes a novel entry point to study the rise of Big Data for climate change resilience, and to explore the role of data within complex and vulnerable freshwater ecosystems. The dataset, collected and analyzed at the site for nearly five decades, provides an increasingly relevant source to inform policy and resilience-building actions. Findings reveal that climate change is already having an impact on:

- *Air temperature, precipitation, and the length of the seasons*, affecting water quantity and many of their physical, chemical and biological properties. For example, over the last decade the Lake Winnipeg basin has seen greatly increased precipitation, which has been linked to increased loading of nitrogen and phosphorus from agricultural lands into rivers feeding the lake. These “extra” nutrients have helped promote large algal blooms in the lake that are associated with poor water quality and beach closures.
- *Shorter winters and a reduced duration of ice cover*, with direct implications for remote northern communities, including road closures and disruptions to activities such as snowmobiling and ice fishing, which are of significant economic importance to local livelihoods. These effects also have impacts on fish such as lake trout, as they require cold temperatures and highly oxygenated water to survive.
- *Water clarity in the lakes*, an important feature that determines how much light and heat penetrate beneath the water surface, and what sorts of species can live there. Variations in water clarity can determine how much plant growth can occur and how much food and energy are available to support the food web. Changes in water temperature can also have a large impact on fish growth, feeding and reproductive success.



Tech Buff Zone

IISD-ELA & THE V'S OF BIG DATA

BIG DATA VOLUME

10's of GB

BIG DATA VELOCITY

Periodic (biological and chemical data) to near-real time (hydrology) to real time (meteorological)

BIG DATA VARIETY

Seven thematic areas (meteorology, hydrology, physical limnology, water chemistry, phytoplankton, invertebrates, and fish)

BIG DATA VERACITY

The data collected is verified through:

- Specialist quality assurance/quality control protocols
- Development underway of automated QA/QC methods
- Inter-laboratory comparisons
- Incorporation of datasets in peer-reviewed journal articles and other scientific literature
- Oversight of scientific review committee



How Does the IISD-ELA Dataset Build Resilience?

The IISD-ELA long-term dataset provides an ever-expanding source of scientific evidence to better understand the impact of shocks and stressors on freshwater ecosystems over time, and to assist key stakeholders (e.g., policy-makers, community members, private corporations) in making evidence-based resilience decisions. It helps build coping and adaptive capacities of key resilience stakeholders involved in freshwater ecosystem management/decision making by:



Strengthening the ability of decision-makers to understand likely causes and effects of actions by documenting the pressures and responses of natural systems to human impacts. While research is most apt for the boreal/ Great Lakes regions of North America, many processes are applicable to communities and ecosystems in temperate regions of the northern hemisphere. Understanding the limits of natural systems to absorb disturbance can help communities decide how to better prepare for change and protect freshwater resources. More broadly, the IISD-ELA dataset contributes directly to climate modelling in Canada (through Environment Canada), improving the ability of national stakeholders to **cope with change** to predict climate change impacts and strategize accordingly.

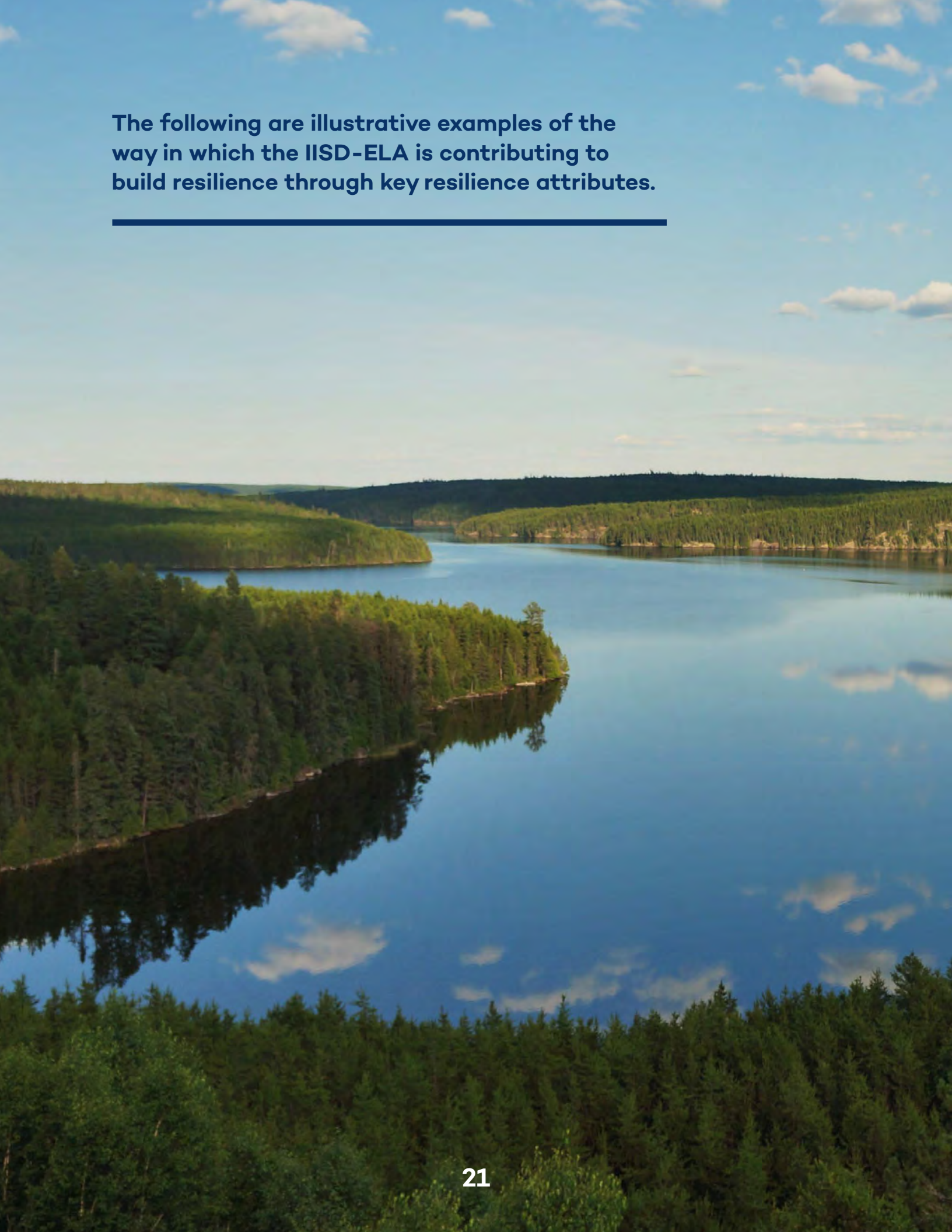


Building the **adaptive capacity** of local First Nations communities by fostering evidence-based decision making and encouraging more effective use of resources to meet local challenges and needs. The IISD-ELA field station is located in Treaty 3 traditional territory. Going forward, it is expected that activities will include collaboration and communication in areas of common interest, including the environmental impacts of resource development, education, youth engagement and traditional ecological knowledge, all of which play a role in resilience building.



By measuring long-term change in unimpacted systems, IISD-ELA provides a strong baseline for the impacts of climate change in the boreal forest. It contributes to **adaptive capacity** by improving the ability of decision-makers to understand vulnerability over time from a whole-ecosystems perspective. This understanding allows them to prioritize management actions based on climate change scenarios.

The following are illustrative examples of the way in which the IISD-ELA is contributing to build resilience through key resilience attributes.



Resilience Buff Zone

IISD-ELA & RESILIENCE ATTRIBUTES



Robustness

It builds robust models to inform decision-making processes of environmental authorities involved in the protection of freshwater ecosystems. The LTER data is a historical dataset and can be used to examine long-term trends and ecosystem variability. It can also be used to build/adapt/validate models that can be coupled with climate predictions to assess future impacts of climate on lakes.



Learning

It deepens the knowledge base of researchers, community members and decision makers about the long-term changes affecting freshwater ecosystems. As part of its community outreach, IISD-ELA is working on communication and educational resources on our freshwater science that can be used by teachers or the general public.



Redundancy

It fosters the production and dissemination of multiple research products to raise awareness and communicate findings in different formats and mediums.



Scale

It provides a platform for researchers from different academic background and countries to interact, collaborate and use their findings to inform policy-making processes. While the IISD-ELA research station is located in northwestern Ontario, the intent is that the data collected can be used to inform resilience building strategies—to climate change and other stressors—more broadly. IISD-ELA datasets are used widely and combined with other datasets to examine regional, national, continental, and global phenomena.



Flexibility

It provides environmental authorities with scientific evidence about change over time, helping to consider different adaptation options.



Equity

It empowers community members through awareness raising and training on scientific findings, and fosters their collaboration with researchers and policy-makers in the design of approaches to better understand and protect freshwater resources and local livelihoods. IISD-ELA also builds collaboration with local Indigenous peoples and seeks to respectfully incorporate traditional Indigenous and local knowledge in land use and scientific processes.



Self-organization

It develops evidence-based frameworks for human impacts to fresh water to encourage more informed local responses to challenges. Those frameworks arise from scientific and advisory bodies or advocacy groups that then work with local policy-makers, stakeholders and communities.



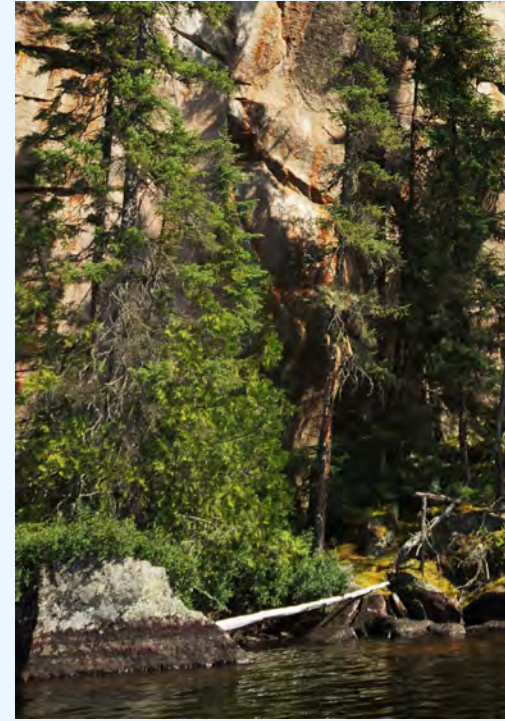
Diversity

It allows researchers around the world to use the data for comparison with other studies such as an examination of lake ice impacts due to climate change. Understanding potential impacts in other regions and their causes provides decision makers with diverse perspectives and pathways of change, including change caused by human disturbance.

Key Lessons Learned: Enabling data's role in policy and practice

Data Access

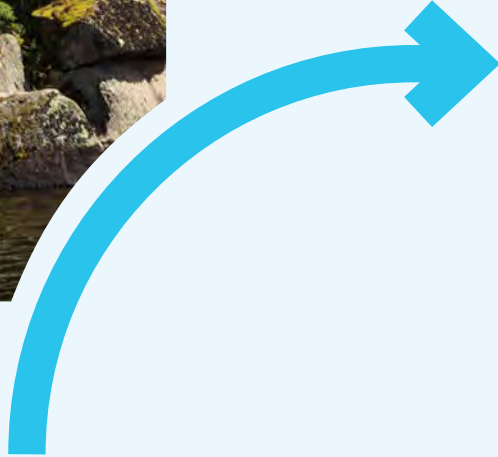
The value of data increases exponentially with size, organization and accessibility: the wholeness of a dataset. Enabling data access is crucial to enable that “whole”—a truly holistic perspective about pathways of change in vulnerable ecosystems. The IISD-ELA long-term dataset can be publicly accessed through a data-sharing agreement with public researchers. Users are encouraged to work with IISD-ELA scientists in its interpretation and publication to foster peer review and collaboration and to include ecosystem contexts. The IISD-ELA website also offers an interactive map with the location of experiments, and an interactive data application to visualize changes in temperature in Lake 239, one of the best-studied lakes in the world.



Data Assessment

When assessing climate change data, time scales matter. The long-term monitoring of physical, chemical and biological parameters of several lakes and streams has been key for detecting the effects of climate change, which take place over years or decades. Data assessment and quality assurance policies continue both in the early stages following collection by IISD-ELA's technical staff, and again as data enters the peer review and journal publication processes.





Data Application

Effective communication of scientific findings is key to ensure their applicability. IISD-ELA findings are continuously communicated to a variety of audiences, through multiple channels. Policy briefs to inform decision making of policy-makers, journal articles for the research community, participatory meetings and consultations with community stakeholders, as well as social media and blogs to raise awareness among the general public.



Data Actionability

Policy influence is a key enabler of data actionability. Research originating at the Experimental Lakes Area has had considerable policy influence, particularly as this research led to universal recognition of the pollution impacts of nutrients to freshwaters. Establishing cross-sectoral partnerships, identifying information gaps and communicating effectively to bridge science with practice are key in ensuring that data translates into action. Past research conducted at IISD-ELA had and continues to have a dramatic impact on policy decisions on North American water management, particularly the research that led to better understanding of the impact of phosphorus on lake eutrophication.¹³

These findings led to many jurisdictions restricting use of phosphorus in residential detergents and implementing municipal treatment for nutrient pollution. Recent research¹⁴ continues to analyze the divergent impacts of phosphorus and nitrogen—the major constituents of agricultural fertilizers and components of livestock runoff that continue to threaten North America’s freshwater resources. Understanding causes supports effective and robust policy decisions and increases public trust in resilience-building activities.



Key Enablers and Challenges



Enabling

Well established reputation and credibility

Credibility is essential for trust. IISD-ELA has a long track record of policy-relevant science in the public eye, monitoring climate, water quality and fisheries. Its reputation as a world-renowned facility in the scientific community has ensured high standards of research and helped build partnerships.

Challenging

Underutilization of the dataset collected at the whole-ecosystem laboratory

The transition from Federally-operated laboratory to non-profit organization broaden data collection and dissemination opportunities for IISD-ELA. Recovering large amounts of non-digitized data continues to be a challenge as does keeping 50 years of data in easily-usable and organized formats.

Challenging

Informing national and international environmental policy

Communicating complex interactions at the interface of human and ecosystem communities requires outreach at multiple levels, from school presentations, science education, and providing expert opinion to corporate government bodies.

Enabling

Community outreach and Indigenous engagement

This outreach is key to meet the needs of local communities and the general public. Activities include tours and events with Northwestern Ontario and Manitoba community members and schools in these areas. IISD-ELA field station is located in Treaty 3 traditional territory. With the support of Tides Canada, IISD-ELA has been building relationships with local First Nations communities and has been working to understand their concerns and needs.

Enabling

Emphasis on experimentation and learning

Engagement of university students and researchers from all over the world in unique experiments that provide multi-disciplinary perspectives about the resilience of freshwater ecosystems.

Challenging

Quality and verification mechanisms

High data variety requires innovative solutions to storage and quality assurance, often requiring multiple areas of expertise from reviewers.

Recommendations

One of the main challenges in the study of climate change consists in disaggregating the effects of climate from other stressors that affect a system's vulnerability. In the case of freshwater ecosystems, the stressors are multiple and varied, and include fishing pressure, changes in land use or changes in industrial activity. IISD-ELA's approach to data suggests that this challenge can be addressed by:

- a) monitoring natural variables in remote locations that are not subjected to man-made pressures, and using them as a reference to identify change, and by
 - a) collecting data over long periods of time, which is more appropriate to understand climate change impacts.
-

Reaching a balance between data openness and quality is not always easy but is necessary to avoid the underutilization of the data. This balance is key to continue strengthening the whole-ecosystem perspective that guides IISD-ELA's approach. Big Data openness goes hand in hand with an expanding network of researchers, practitioners and decision makers that play a role in resilience building.

IISD-ELA continues to transition from an academic-government focus, to broad public outreach and communication about freshwater issues and the complexity of environmental impacts. Ensuring an open and transparent science communication framework will increase public understanding of climate change impacts on freshwater resources and communicate more effectively the large and complex dataset recorded at IISD-ELA.

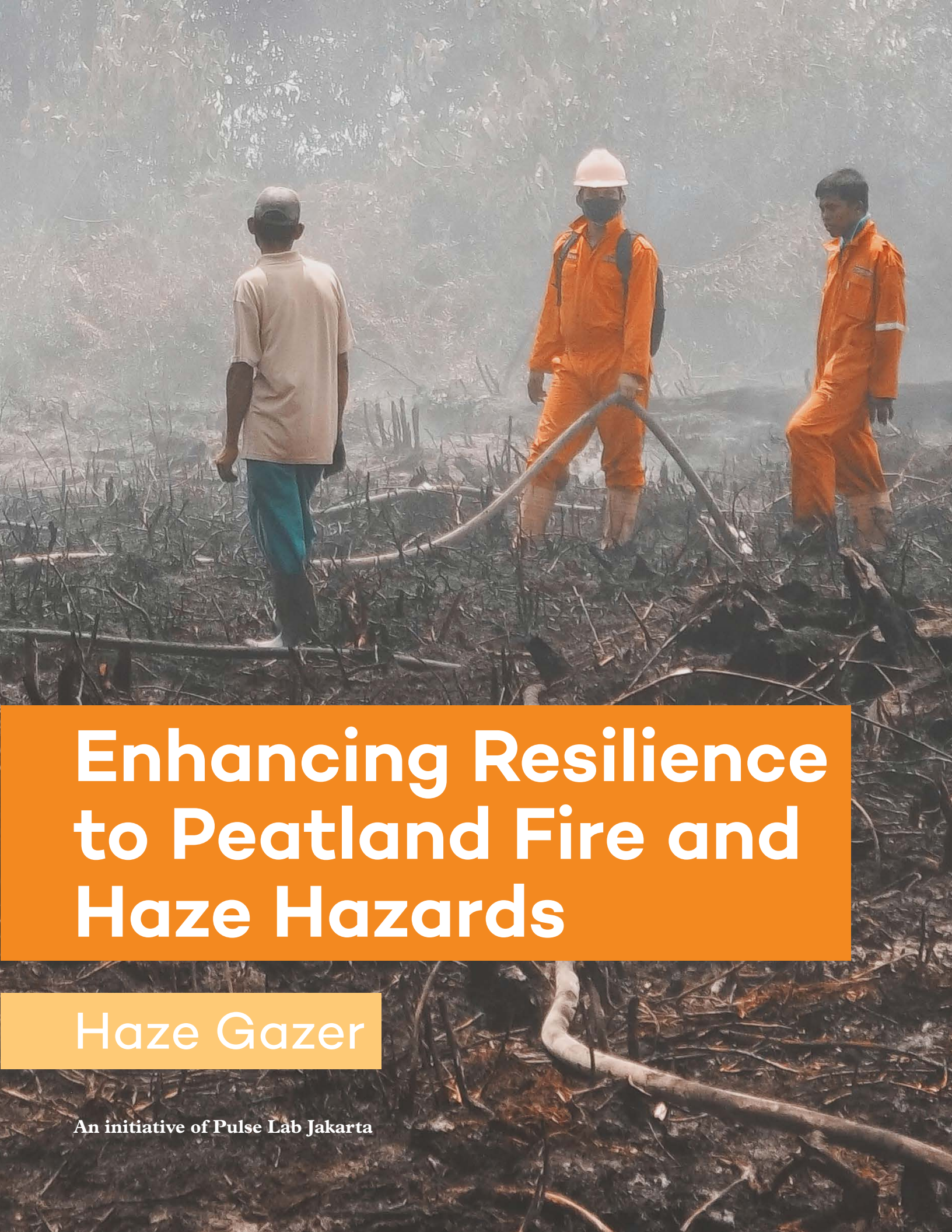
Resilience is best understood from a holistic perspective. There still much to learn from IISD-ELA's unique whole-ecosystem laboratory setting in terms of its approach to strengthen the resilience of freshwater ecosystems to climate change stressors.



Additional Information:

- <https://www.iisd.org/ela/>
- Climate Blasts Series: <https://www.iisd.org/ela/blog/news/iisd-ela-climate-change>
- <https://www.iisd.org/ela/blog/news/water-brothers-visit-us-learn-climate-change/>

This case was prepared by the author with contributions from Geoffrey Gunn, Pauline Gerrard and Scott Higgins, IISD-ELA.



Enhancing Resilience to Peatland Fire and Haze Hazards

Haze Gazer

An initiative of Pulse Lab Jakarta

Rural and urban communities in Indonesia (and neighbouring Southeast Asian countries) often experience the devastating effects of forest and peatland fires on their livelihoods, health and quality of life. During the 2015 dry season, fire devastated 2.6 million hectares of land (6.4 million acres) in Indonesia.¹⁵ In addition to increased air pollution, school closures and public transport disruption, biodiversity was threatened by further loss of habitat, and a massive amount of carbon dioxide was released in the atmosphere—reaching an alarming rate of 15 to 20 million tonnes per day at the fires’ peak. These impacts are particularly devastating for Indonesia’s tropical forests, one of the most diverse habitats on the planet.

Episodes of forest and peatland fires, such as the 2015 case in Indonesia, are becoming more common. These fires and associated impacts result in human, natural and financial losses that challenge development progress throughout the region.

Tracking and managing the impacts of peatland fire and haze events has become crucial to ensuring more timely and effective responses to these shocks, and to building the resilience of vulnerable communities and institutions that are at the front lines.

Resilience Snapshot	
HAZE GAZER & CORE RESILIENCE QUESTIONS	
RESILIENCE WHERE?	Indonesia
RESILIENCE OF WHAT?	Disaster management institutions
RESILIENCE OF WHAT?	Forest and peatland fires
RESILIENCE FOR WHAT PURPOSE?	Improved quality of life of communities affected by fire and haze hazard
RESILIENCE HOW?	Strengthening the coping and adaptive capacity of institutions through improved access to real and near-real time data and visualizations needed to inform decision making

Supporting Resilient Responses to Fire and Haze Hazard

Traditional approaches used to gather and access data (e.g., satellites and static data on population density and distribution) are nowadays insufficient for authorities to effectively respond to forest fire haze events, and to fully understand the needs and dynamics of affected communities, such as what people do and how communities cope during such disasters.

Pulse Lab Jakarta developed Haze Gazer to help disaster management units analyze and visualize haze crises, bringing together real-time information from a variety of data sources and enhancing individual and system-wide decision making. The tool uses advanced data analytics to mine data sources, which is crucial to inform decision-making efforts in areas affected by fire and haze events.



Tech Buff Zone

HAZE GAZER & THE V'S OF BIG DATA

BIG DATA VOLUME

TB (as the original data pool comprises tweets)

BIG DATA VELOCITY

Near-real time, real time

BIG DATA VARIETY

- Fire hotspot information from satellites (Global Forest Watch).
- Baseline information on population density and distribution.
- Citizen-generated data, including the national complaint system in Indonesia called LAPOR!
- Citizen journalism video uploads to an online news channel.
- Real-time big data such as text-, image- and video-oriented social media (e.g., YouTube, Instagram).

BIG DATA VERACITY

Various methods are applied to filter relevant content and ensure the quality of the data collected, including a filtering protocol to ensure the quality of the images.



How Does Haze Gazer Contribute to Building Resilience?

Access to this wide range of data and insights has played a key role in strengthening the capacity of affected communities in Indonesia to cope with the impacts of forest and peatland fires and has helped inform government strategies related to planning for and responding to these events. The tool's aim is to assist with building coping and adaptive capacities by:



Enhancing disaster management efforts by providing **real-time insights** to inform local response (e.g., location of fire and haze hotspots, strength of haze in population centres, location of vulnerable populations).



Providing information that relevant organizations can use to develop and refine **response strategies** of affected populations (e.g., movement patterns and in situ behavioural changes), enhancing absorptive capacity in the event of disasters.



Enabling Indonesia's local and national disaster management authorities to **target their interventions** and **align their efforts** with affected populations to increase their resilience to fire-related hazards.

The following are illustrative examples of the ways in which Haze Gazer contributes to building resilience to fire and haze hazards in Indonesia by strengthening key resilience attributes:

Resilience Buff Zone

HAZE GAZER & RESILIENCE ATTRIBUTES



Robustness & Rapidity

It strengthens the capacity of Indonesian disaster management authorities to access real-time situational information, track and manage the impact of fire and haze events in a timely manner.



Scale

It integrates data from sources at multiple levels (e.g., satellites and baseline information on population density and distribution, citizen-generated data) to provide a more holistic situational analysis in the event of fire and haze events.



Diversity

It utilizes a variety of technologies (GIS data, Big Data analytics, text processing, image processing, social media mining, air quality and visibility sensors) to enable access to a larger and more diverse pool of data sources (e.g., satellite imagery, government databases, citizen-generated data) to inform disaster management efforts.



It combines the dynamics of real-time social signals with statistical information such as population distribution and point-of-interest (e.g., locations of schools and hospitals).



Equity

It provides real-time, high-resolution data on the location of the most vulnerable populations, in order to ensure that they receive adequate emergency response support.



Learning

It increases user understanding about actual conditions in the field with charts and maps, and improves their analysis of the situation.

Key Lessons Learned: Using Big Data for peatland fire and haze resilience



Data Access

Access is not only about mining data sources, but also about providing the user with clear and relevant “entry points” to the dataset. The Haze Gazer platform includes specific selection criteria by (a) *Region/Province and Timeline* (data on a specific location or region during a specified timeframe) and (b) *Baseline* (hotspot distribution and cluster points). These access criteria allow users a more in-depth analysis of peatland fire and haze events. Development of a mobile-ready version of the website allows more users to access the data.

Data Assessment

The ability of the user to assess the data more effectively is key to ensure resilience impact. Haze Gazer allows users to analyze and visualize the data through a single, user-friendly dashboard. It combines information from social media data and the national complaint system to provide information on the locations of fire and haze hotspots, the strength of haze in population centres and the location of the most vulnerable cohorts. Users can also monitor trends on what affected populations are saying and reporting on haze, including health conditions, socioeconomic impacts, related social media hashtags and Instagram posts.



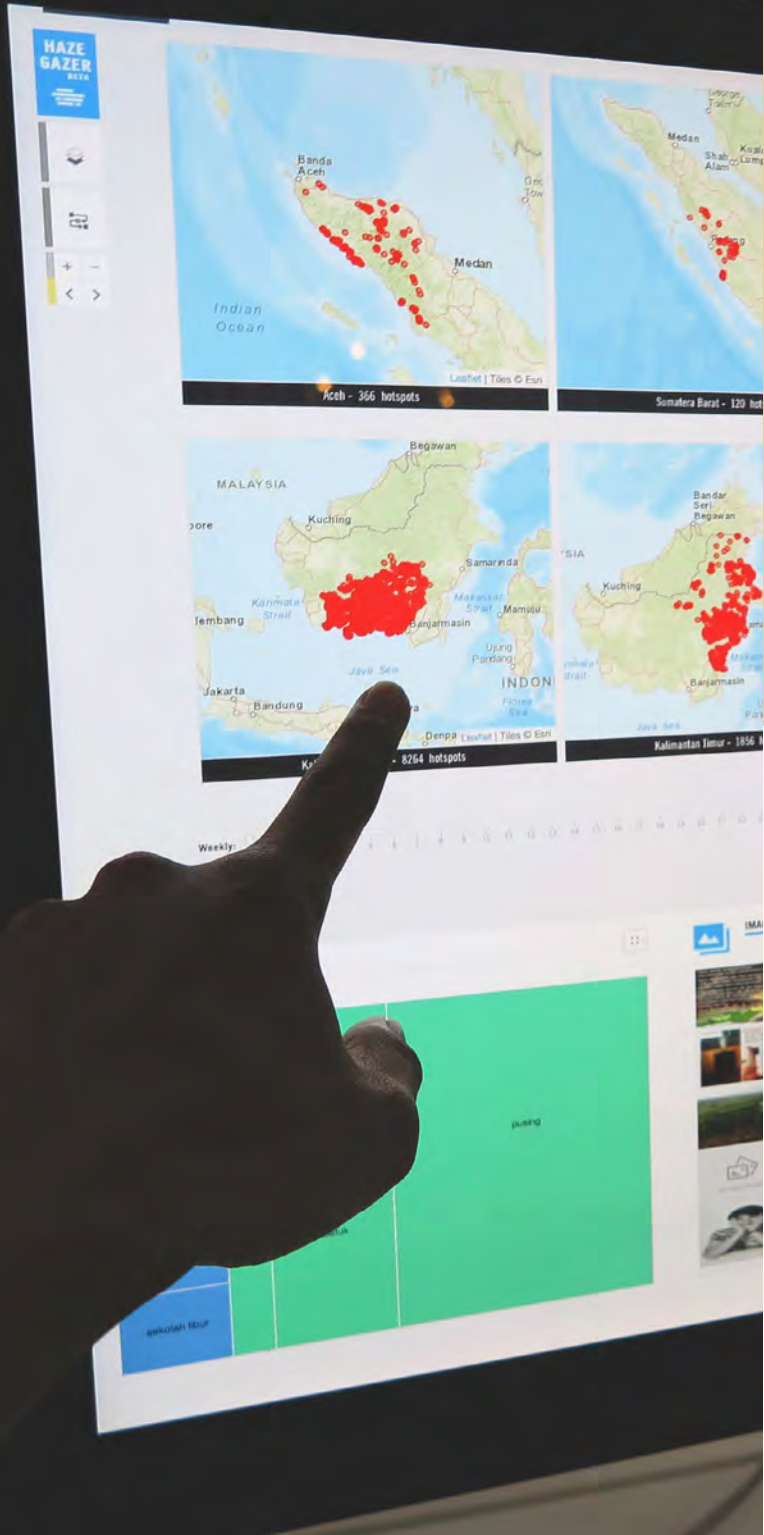
Data Application

Ensuring privacy is key to foster Big Data's role in decision-making processes. Haze Gazer's methodology uses aggregation and a degree of user-anonymity to preserve the privacy of individuals and groups. Data is collected from national complaint systems and public online media sources to identify peatland fire and haze hotspots and target emergency response at the meso level—such as community or regional level—not the micro level. The content is filtered by relevant keywords for topics of interest and only that information is made available for analysis. The dashboard may also be used to monitor scenarios beyond haze crises in the area, by feeding in relevant data sources.

Data Actionability

Practitioner engagement is crucial to ensure that Big Data applications are relevant, and that the information and knowledge are actionable. Haze Gazer is installed in the President of the Republic of Indonesia's situation room and is currently being tested—and improved—with feedback from disaster management practitioners.

Key Enablers and Challenges



Enabling

Implementing data innovation through multisectoral partnership

Pulse Lab Jakarta was established through a partnership between the United Nations and the Government of Indonesia, and collaborates with the public sector, the UN country team, communities and leading private sector companies.

Challenging

Maintaining the balance between data quality, relevance and variety

Addressing the need to strengthen the tool by including additional types of data (such as meteorological data) while at the same time ensuring data veracity.

Challenging

Tracking action

Tracking the transition of data into actual coping actions is challenging. This could be strengthened by publication of operational practices of disaster management authorities, which would allow the platform to capture insights on both operational potential and real-world haze crisis dynamics.

Enabling

Innovative approaches

Developing novel approaches can help foster citizen engagement and broaden the data sources, including designing games to incentivize the crowdsourcing of regular images in order to assess shock intensity.

Enabling

Addressing citizen engagement and empowerment on a constant basis

A crucial component of data innovation is to provide mechanisms to engage and empower citizens through the production, the access and the use of data. This is facilitated by a clear institutional mandate and partnerships.

Challenging

Scaling up to different contexts

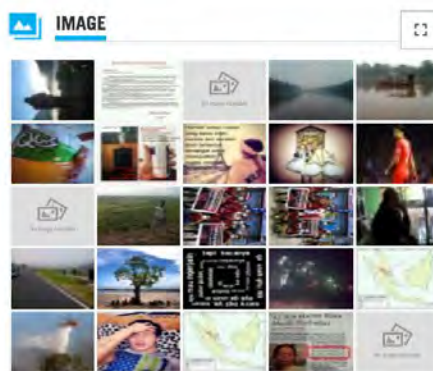
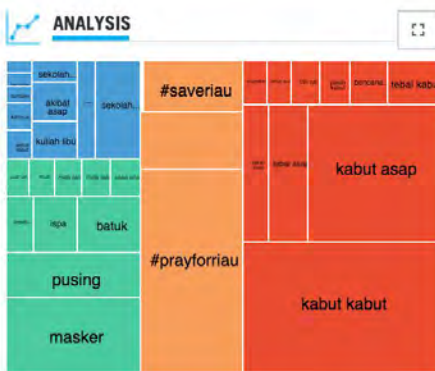
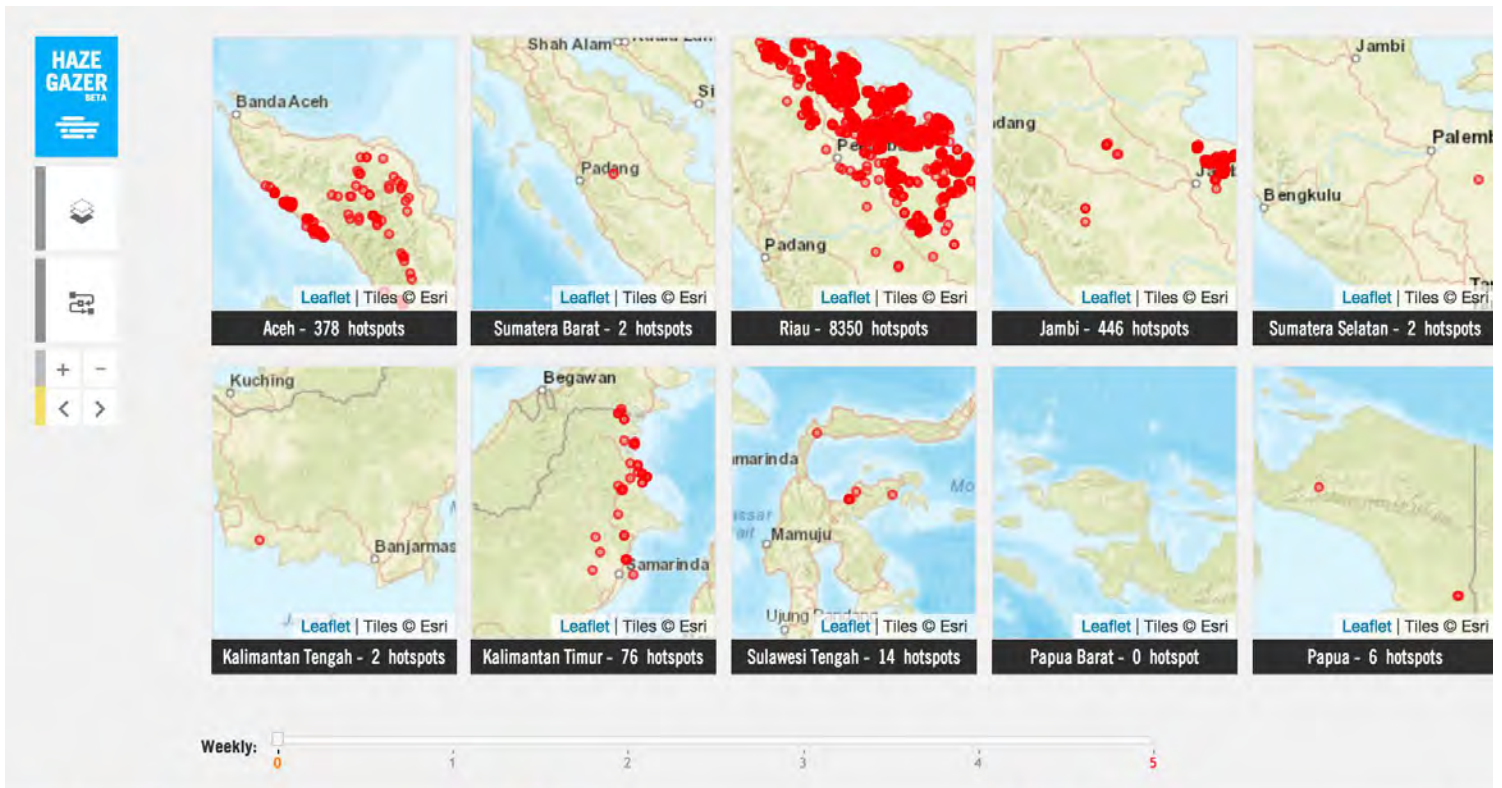
Applying the platform to a different context, for instance, the monitoring of social signals around cyclones in the Pacific region and beyond.

Recommendations

Diversifying data sources is a powerful component in resilience-building efforts. In particular, integrating data sources from governments can be crucial to ensuring endorsement, credibility, and adoption among decision makers. By combining hotspot satellite information and data from Indonesia's national complaint system LAPOR! with online social media analysis, Haze Gazer provides real-time insights on disaster impact and recovery on the ground, helping to inform government decision making.

Scale matters. Big Data practitioners need to identify financially and technically viable mechanisms to replicate, adapt and apply tools to wider regional contexts that are impacted by similar shocks, and that could benefit from a more articulated approach to humanitarian efforts (e.g., Haze Gazer expanding to Southeast Asia to inform haze-related humanitarian efforts and to improve regional resilience). Scaling up also involves expanding data access to a broader set of users (e.g., the general public), as well as deepening insights by integrating richer data sources (e.g., sensors).

Implementation should go hand in hand with research and learning. Pulse Lab Jakarta is conducting research to better understand how residents in haze-prone areas gather information on haze and haze-related impacts, and how they share this information with their networks. Further research is needed to verify the potential of alternative data sources to build resilience to forest and peatland fires, including the use of sensor data and other citizen-generated data to foster accountability and improve information sharing tools and feedback mechanisms.



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Additional Information:

- <https://www.unglobalpulse.org/projects/haze-gazer-a-crisis-analysis-tool>
- <https://www.unglobalpulse.org/news/scaling-up-haze-gazer>
- <https://www.unglobalpulse.org/blog/haze-gazer-crisis-analysis-tool>
- http://un.or.id/el_nino/images/download/Haze-Gazer-FINAL.pdf
- <https://www.newscientist.com/article/2139177-wildfires-killer-haze-tracked-with-twitter-as-it-spreads/>

This case was prepared by the author with contributions from Dwayne Carruthers and Jonggun Lee, United Nations Global Pulse – Pulse Lab Jakarta.



Strengthening Urban Resilience Through Community-based Mapping

Dar Ramani Huria

An initiative of the World Bank funded by the UK Department for International Development (DFID) in partnership with Humanitarian OpenStreetMap Team, Tanzania Red Cross, Ardhi University and the City of Dar es Salaam

When the annual flooding arrives, life in Dar es Salaam comes to a standstill. In slum areas such as Tandale, roads become impassable and deep mud makes even a short walk to school impossible. Hospitals are closed, and businesses halt their operations, affecting the livelihoods of thousands of people. These impacts are prevalent in the unplanned and informal settlements that abound in the city, costing Dar es Salaam significant resources in emergency response, damage to infrastructure, and loss in income and livelihoods, to name but a few.

The human and economic losses of natural floods are exacerbated by the lack of adequate planning, ultimately slowing down the city’s growth and reducing the opportunities for its most vulnerable inhabitants to emerge from poverty.

Despite the importance of quality mapping for decision making, developing countries like Tanzania lack sufficient incentives for mapping companies to develop quality data. Maps that are

produced remotely are often inaccurate, outdated, or contain insufficient data for decision makers to plan and make decisions in the event of disasters. Access to and use of detailed, up-to-date maps has become vital to improve disaster planning and response in flood-prone areas of the city, and to enhance its capacity to cope with and adapt to the impacts of shocks and stressors.

Resilience Snapshot	
DAR RAMANI HURIA & CORE RESILIENCE QUESTIONS	
RESILIENCE WHERE?	Dar es Salaam, Tanzania
RESILIENCE OF WHAT?	Community members, ward leaders, disaster management institutions
RESILIENCE OF WHAT?	Floods
RESILIENCE FOR WHAT PURPOSE?	Improved ability to prepare for, respond to, and adapt to a changing climate, as well as to withstand and rapidly recover from shocks.
RESILIENCE HOW?	It improves the coping capacity of institutions through access to community-based maps to inform decision making and strengthening general awareness among community members about disaster hazards and risks.

OpenStreetMap

A web-based platform and global community working to create a free and open map of the entire world, constitutes a sound tool to build resilience in vulnerable regions, enhancing economic development, emergency response and urban planning, among other development goals. *Dar Ramani Huria* (Swahili for “Dar Open Map”) responds to the need for a novel approach to enhance the city’s resilience to flooding through quality community-contributed data. Through the production of highly accurate maps of flood-prone areas, the initiative builds general awareness about flood-related risks, fostering local responses and community-level action, and allows decision makers to better plan for and respond to flood-related events, strengthening their capacity to cope with future disasters.

Dar Ramani Huria

Building Resilience One Open Map Contribution at a Time

No one is better positioned to map their environment than the community members who inhabit it. Through the engagement and training of university students and community members, Dar Ramani Huria develops community-based maps in flood-prone wards of the city. The maps are used to run flood impact scenarios based on open source tools QGIS and InaSafe, a free software that allows users to run natural disaster scenarios. After community members collect the data through multiple tools, Dar Ramani Huria mappers help to develop the maps by digitizing their content via OpenStreetMap.



Tech Buff Zone

DAR RAMANI HURIA & THE V'S OF BIG DATA



BIG DATA VOLUME

- 145 MB of open map data in OpenStreetMap
- 7 GB compressed of aerial drone imagery for Tanzania in OpenAerialMap
- 100 GB of street view photography in Mapillary (45,000 images—22,000 of which are 360° images—370 unique km, 780 km)



BIG DATA VELOCITY

Real time



BIG DATA VARIETY

- OpenDataKit/OpenMapKit Surveys
- Open Geospatial data in OpenStreetMap
- Drone imagery (OpenDroneMap/OpenAerialMap)
- Street view photography (Garmin VIRB camera, Trimble MX7 Mobile Mapping Imaging system, Mapillary mobile phone application)
- Satellite data. Aerial imagery from the following sources: Bing, UAV, Mapbox, DigitalGlobe Standard and DigitalGlobe Premium



BIG DATA VERACITY

The data collected is verified through the following tools and technologies:

- The [MapCampaigner](#) application serves roles in remote mapping, field mapping and quality assurance.
- [OSMAntics](#) to derive overall statistics and inspect keys/values and visualizations.
- HOT Export tool, to perform bulk downloads of the entire OpenStreetMap dataset for use in QGIS and other GIS platforms for advanced analysis and correction.
- [JOSM](#) validation, using a combination of the built-in validation tool itself and filters to spot common errors such as misspelled tags and concentric or overlapping building polygons.
- Validation procedures as defined by the OSM Wiki guidelines (specifically updated to reflect Ramani Huria procedures).
- Topology correction and digitization rules from the QGIS (and GRASS) toolkits to validate error prone layers such as administrative divisions.
- [Network analysis](#) using the OpenEarth Python-based toolkit developed by Deltares, which allows personnel to verify the fitness of drainage mapping data for use in hydrological modelling. This provides a daily feedback loop for drainage mapping teams to ensure that their work is complete (topologically connected) and contains the elements specified by the data model.
- The [Hydro-OSM](#) data quality assurance model to automatically identify errors, warnings and missing information of drains. This method specifically checks attributes relevant to urban drainage. For cases of missing information or errors field teams will revisit the site and fix the error.





How Does Dar Ramani Huria Build Resilience?

Community-based maps can be powerful tools for change. Accurate and detailed maps can serve as guides for all realms of development with a particular focus on improving flood resilience, as the experience of Dar es Salaam demonstrates. Open community-based maps help build coping and adaptive capacities by:



Providing decision-makers and communities with detailed maps of areas, roads, streams, floodplains, and other relevant features, to strengthen risk identification and awareness raising about climate risk and uncertainty, while strengthening community and institutional **coping capacities** for disaster planning, prevention, and response.



Equipping community members and ward leaders with the skills required for data mapping, digitizing and modelling risk. The skills acquired by mappers are widely applicable to a number of areas, contributing to their ability to diversify their livelihood options and **adapt** to change. Adaptive capacities are also strengthened by equipping students and future decision-makers with mapping skills, improving the capacity of the planning sector to innovate and generate data through community involvement.

The following are illustrative examples of the way in which Dar Ramani Huria is contributing to build resilience in Tanzania, through key resilience attributes.



Resilience Buff Zone

DAR RAMANI HURIA & RESILIENCE ATTRIBUTES



Self-organization

It empowers community members to map their own neighbourhoods, identify flood-prone areas, and engage in planning processes. Higher community involvement contributes to awareness and preventive actions at the local level (e.g., cleaning local drains to mitigate flooding impact). OpenStreetMap is a technology platform, but through the process of mapping the initiative is expanding networks, building bonds and personal connections that can facilitate self-organization in response to multiple shocks and stressors



Robustness and Rapidity

It creates sophisticated and highly accurate maps of Dar es Salaam to strengthen the decision-making process of the city's disaster management authorities, and speeds up responses to disasters based on up-to-date information on flooding impacts.



Learning

It raises awareness of the need for flood prevention and risk reduction at the local level, by providing capacity building on technical skills (computer and mapping skills) that can be broadly applied by community members, and by making the training materials publicly accessible. Part of the theory of change of this initiative is that the hundreds of young people who have worked on the project will spread their increased skills and awareness of risk among their families and throughout their future careers. The project team is working on a partnership with Ardhi University to create formal classroom curricula based on the experience.



Equity

It fosters inclusion through community engagement, and maps vulnerable areas of the city that were previously “off the map,” and makes all maps freely available. The project has purposely focused on achieving a gender balance of female university students, many of whom have taken leadership roles on the project. Activities involve people of all ages, both young (university) and older community members in collecting data.



Redundancy

It applies complementary methods to capture the highest-quality and most detailed imagery possible to feed into area maps (e.g., several technologies are used to capture street view and aerial imagery).



Diversity

It combines community maps with other data in InaSAFE to run realistic natural disaster scenarios. The maps can be downloaded in both SHP format—OSM data—and PDF format for already-designed maps, and also delivered in printed form to the local governing bodies of each ward.



Scale

By using the OpenStreetMap platform, community mappers from Dar es Salaam are connected to a vast global network of mappers, researchers, developers and development practitioners. Multi-scale linkages have also formed among the diverse group of stakeholders involved in Tanzania (the Tanzania Red Cross, the local technology community and NGOs like HOT, municipal council and ward leaders).

Key Lessons Learned: Big Data, open maps and resilience building

Data Access

Ensuring data accessibility requires the adoption of flexible approaches. Ramani Huria combines three data collection methods all using free and open source online software accessible to anyone:

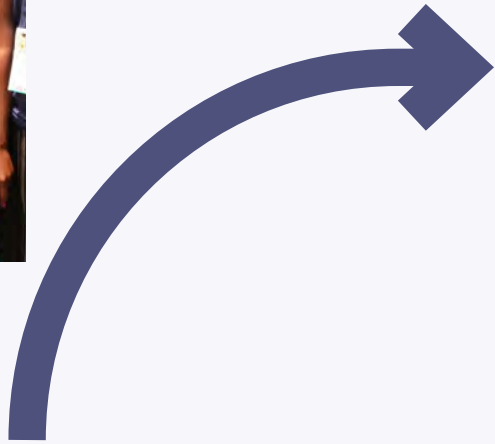
- *Remote mapping:* Students work on their laptops to digitize the roads and buildings they see in satellite or drone imagery.
- *Field mapping using GPS devices:* Students, trained community members and Red Cross volunteers use handheld GPS and maps printed from JOSM or the “Field Papers” app to take note of details in the field, and later digitize them into OpenStreetMap.
- *Intuitive mobile apps:* Applications like OpenMapKit and OpenDataKit are free, open source, and provide custom data collection forms. Teams on the ground add data with a few taps and short text responses.

All data collected is uploaded to OpenStreetMap and is immediately available to all project stakeholders and the general public in multiple formats including web maps, print/pdf maps and downloadable data such as shapefiles for use in GIS applications.

Data Assessment

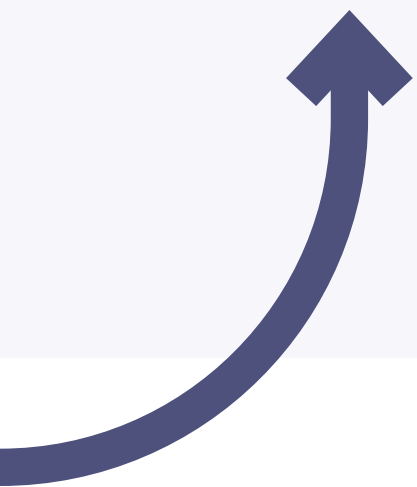
Effective data assessment is enabled by high-quality digitalization and visualization techniques. Dar Ramani Huria provides a robust capacity-building program for local mappers on the use of the desktop application, Java OpenStreetMap Editor (JOSM), through which data can be directly added to OpenStreetMap. It also combines high-quality aerial photography for mapping (through open drone technology) with street view imagery. This allows mappers to create richer and more detailed maps of the area, and enables users to conduct better assessments in flood situations.





Data Application

Data application depends largely on the data's relevance. Dar Ramani Huria ensures relevance by enabling community mappers to identify the areas that are most detrimentally affected by floods in the city. These areas constitute the focus of the mapping exercise. Data is gathered on key topics needed to inform decision making in cases of flood (e.g., drainage, roads and buildings and inundation conditions). When the maps are finished, they are combined with other data in InaSAFE to run realistic flooding scenarios, allowing communities and decision-makers to apply the data in disaster planning and other development processes.



Data Actionability

Training and accompaniment are crucial to ensure actionability. In Dar es Salaam, map findings are collected and used in the development of tailored training in disaster preparation for ward officials and community members. Dar Ramani Huria has digitized every building and roadway in greater Dar es Salaam visible in currently available aerial imagery, including 950,000 buildings (home to an estimated 5 to 6 million people) mapped, as well as 16,000 km of roads, providing officials with valuable tools to inform development. These maps are used to take local action where problems have been identified—for example, if there is a clogged drain causing flooding, the “Adopt-A-Drain” program facilitates monitoring and cleaning. The maps are also being used by ward leaders to locate sources of a cholera outbreak.



Key Enablers and Challenges



Enabling

Exploring new technologies for higher-quality imagery

Aerial photography for mapping in Dar es Salaam used to be challenging due to cloud cover or low image quality. The lack of clear, recent and high-resolution imagery affected accuracy. In response to that, drones are used to ensure the highest quality of imagery for the community mappers.

Challenging

Hazardous physical conditions during flood events

During annual flooding events, local mapping teams can face hazardous conditions. This limits their access to flood-prone areas of the city and can pose safety risks.



Challenging

Complexity of drainage networks

While drainage mapping is critical to flood resilience, the drainage network in Dar es Salaam is extremely complex. Larger water bodies (streams, rivers and canals) are connected to multiple water bodies, both feeding into and draining water from them. Precipitation in the wider catchment area also affects their behaviour. The team is currently collaborating with Deltares on better hydrological modelling of the city.

Enabling

Training toward long-term sustainability

Training community members in mapping contributes to the long-term sustainability of the map, as these individuals can continue editing the map, thus reducing the likelihood the map data will become out of date.

Enabling

Going beyond immediate response in highly flood-prone areas

Decision making in times of a disaster is a complex process. By selecting the most vulnerable areas to map and by highlighting critical issues (e.g., mapping data on drainage, roads and buildings, and inundation), the initiative enables more effective response, but also resilience—by gathering data that can be used to decrease/mitigate some of the risks of flooding, and also decrease potential impacts/damage (both to people and infrastructure).

Challenging

Building local capacity and trust

Knowledge about open data and open source technology is still relatively new, and learning takes time. Building trust is also essential—some community members living in unplanned areas are reluctant to provide data to outsiders due to fears of home demolitions and potential taxation. Working with residents to train them to survey neighbours has helped overcome this challenge, as well as organizing community workshops and discussions before starting to work in a ward.

Recommendations

To play a role in resilience building, Big Data needs to translate into local-level actions. Working in partnership with communities and local leaders is essential to ensuring this. Dar Ramani Huria works with sub-ward level leaders, geotagging contextual information such as vulnerable groups, risk areas, waste, community assets, and community “comments” on risk management. More in-depth geocoded data layers developed with communities feed into broader community dialogue, risk reduction strategies and planning processes.

Big and Open Data can contribute to building resilience by acting as catalysts for new partnerships and collaboration. Open community maps can inform broader resilience-building efforts in the area and foster the articulation of efforts among development stakeholders. In the case of Dar Ramani Huria, the initiative has enabled new partnerships between the Tanzania Red Cross, the local technology community and NGOs like HOT, municipal council and ward leaders.

The impact of Big Data in resilience-building processes does not happen overnight. Integrating new data sources and tools as part of routine decision making is a long-term process requiring local engagement and sustainable approaches. Building local capacities and trust is vital to foster empowerment and continuity over time. Organizing community workshops and discussions at the project onset is crucial to address community concerns and raise awareness on the role of Big Data (e.g., for identifying which houses are built in dangerous areas—and to be able to warn people living in those areas, or considering to move or rent there).

Data quality assurance is one of the most critical aspects that contribute to actionability. Manually identifying errors, missing data and warnings can easily become time consuming, tiresome and inconvenient. Constant review, testing and exploration of new methods and technologies can allow teams to detect problems on time, identify cost-effective solutions and innovate to ensure the highest data quality.



The cost/effectiveness and sustainability of free/open source software is a powerful component in community-based approaches to resilience.

Dar Ramani Huria has collected better, more complete and up-to-date data on Dar es Salaam than has ever existed. It was all done by training community volunteers, working with university students, and forming partnerships. Free and open source software and local devices (students own smartphones) means that everything needed to continue the project and keep data updated as the city changes is already present in the community. There is no need to import equipment or pay software subscriptions.

Additional Information:

- <http://ramanihuria.org/>
- Tanzania Urban Resilience Program:
<http://www.worldbank.org/en/programs/tanzania-urban-resilience-program>
- <http://www.hotosm.org>

This case was prepared by the author with contributions from Tyler Radford, Paul Uithol and Ivan Gayton, Humanitarian OpenStreetMap Team.



Informing Resilience Pathways

The Resilience Atlas

An initiative of Conservation International

Making informed decisions is one of the most complex aspects of building resilience. Every day, governments, communities, donors and businesses around the world make decisions that affect the lives and livelihoods of vulnerable people and the sustainability of fragile ecosystems affected by natural and human-caused shocks and stressors.

In regions such as the Sahel, the Horn of Africa, and South and Southeast Asia, resilience decision making involves managing risks and uncertainties associated with climate change, conflict and population growth, among other development challenges. Crucial data and information needed to inform decisions is often unavailable, or is difficult to access, analyze and visualize in user-friendly formats.

While development stakeholders dedicate an increasing amount of human, technical and financial resources to gathering data, monitoring progress and producing information about the impact of their initiatives, these resources are frequently underutilized, unknown or inaccessible to the broader development community. This data could play a key role informing more effective resilience pathways in complex developing regions.

The scarcity of quantitative, multi-scale and data-driven analyses to inform resilience thinking and programming constitutes a challenge faced by

resilience stakeholders around the globe. The advent of digital technologies and a growing network of sensors and internet-connected data streams provide an unprecedented opportunity to harness the torrent of publicly available data, and communicate it in a more holistic and integrated fashion. Communicating data and trends in a simple, web-accessible format has become vital not only to inform decision making, but also to shorten the pathway between scientific evidence, policy and resilience practice.

Conservation International (CI) developed the Resilience Atlas to provide decision-makers with evidence-based insights on the magnitude of development challenges, and on which kinds of resilience interventions and investments could make a difference based on a large amount of publicly provided data from multiple sources.

Resilience Snapshot

THE RESILIENCE ATLAS & CORE RESILIENCE QUESTIONS

RESILIENCE WHERE?

Global with initial focus on the Sahel, Horn of Africa and South and Southeast Asia

RESILIENCE OF WHAT?

Rural livelihoods, production systems, and ecosystems

RESILIENCE OF WHAT?

Rainfall, temperature, surface water, population, conflict, forest change and natural disasters

RESILIENCE FOR WHAT PURPOSE?

Reduce the vulnerability of livelihoods, production systems and ecosystems to a variety of shocks and stressors

RESILIENCE HOW?

Articulating disparate data sets to inform investment, development and security decisions towards increased resilience

Resilience Atlas

Strengthening Resilience Decision Making

The Resilience Atlas is an interactive analytical tool and database that strengthens resilience decision making in several ways. The geographic nature of the tool allows users to focus on specific regions and determine how shocks and stressors could affect different places, while the diversity of data sources allows them to pull together the most relevant information from over 60 of the best available datasets that help to define resilience. The outputs are presented in easy-to-understand maps that can shift focus from regional to national scales, and—where the availability and resolution of the data permit—to local scales.

The tool's design is also conducive to user empowerment: with the “Journeys” feature, the Atlas guides users on how to tell stories with data, enabling them to explore the specific data that is relevant to the questions they want to answer.

Instead of telling them the answers, the Atlas helps users discover them for themselves following a simple three-step approach:

1. Select geography and system of interest to produce a map of how it is distributed.
2. Identify the stressors and shocks affecting system, and their extent and severity.
3. Explore what kinds of assets (such as natural, human, social, financial, and manufactured capital) might increase resilience.

Users can share their insights by sharing map links via social media or by embedding Atlas data within their own webpages. All of this data is openly available without a fee. The site supports Application Programming Interface (API) access for direct access to the raw data by private industries, allowing a broader audience to work with the data to build other tools.



Tech Buff Zone

THE RESILIENCE ATLAS & THE V'S OF BIG DATA

BIG DATA VOLUME

Analysis of more than +12 TB

BIG DATA VELOCITY

Periodic

BIG DATA VARIETY

- Data from satellites
- Ground-based biophysical measurements
- Household surveys
- Data from more than 60 data sets, including the [NASA NEX climate projections data set](#)

BIG DATA VERACITY

The data collected is verified through guidance from scientific experts in each field on the best available datasets to characterize resilience. The datasets used are peer reviewed or come from internationally recognized authorities such as the Food and Agriculture Organization of the United Nations (FAO), United States Agency for International Development (USAID), and the World Bank, among others. The original publications are also listed with the datasets in the Atlas, and can be extracted for reference.



How Does the Atlas Build Resilience?

The Atlas provides insights into the vulnerability of particular systems and strengthens resilience by enabling a more evidence-based approach to decision making. The tool contributes to many resilience capacities:

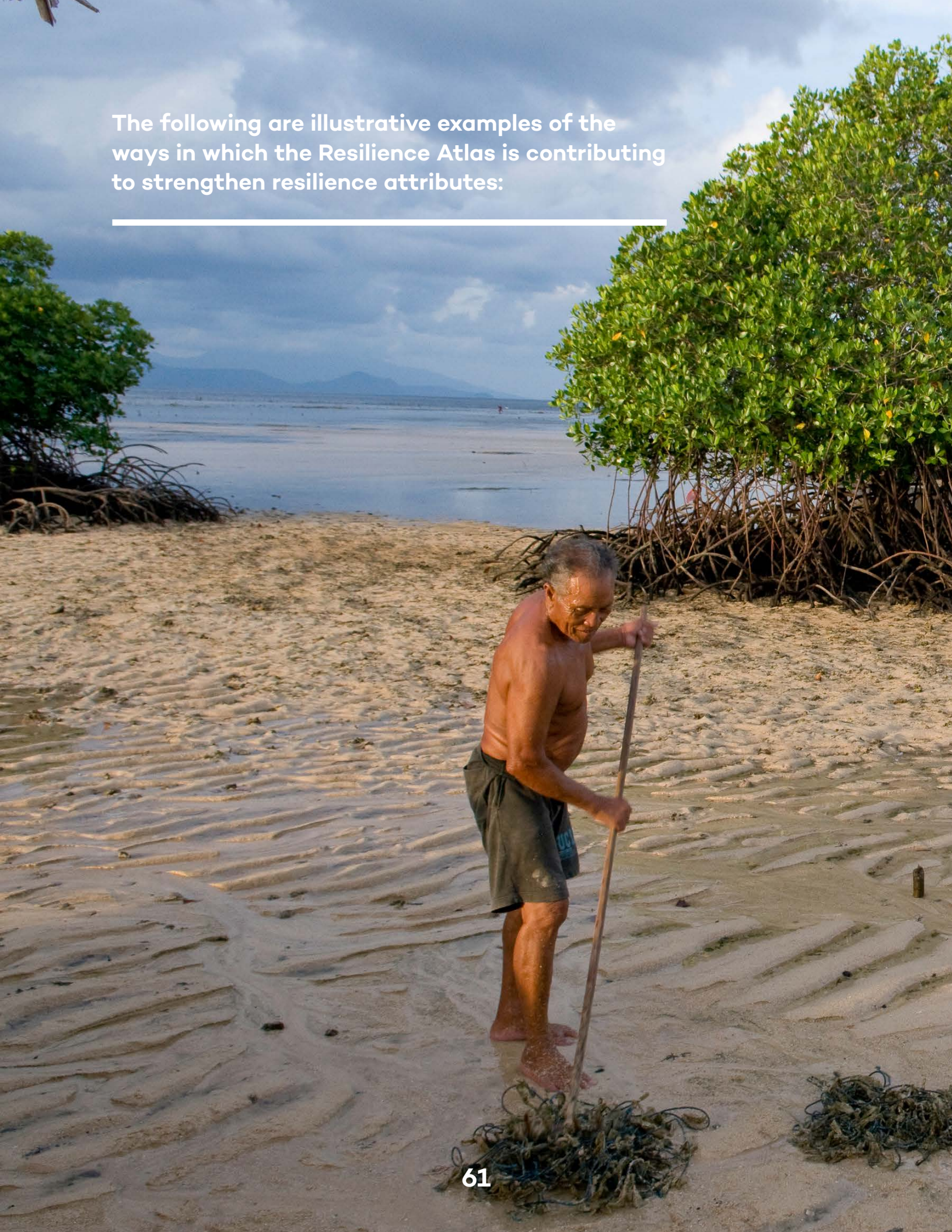


By enhancing resilience **programming and investment decisions**, pulling together the best data from multiple sources, providing decision-makers with a more complete, multi-scalar, evidence-based perspective. By mining data, users can understand which kinds of interventions and investments have actual evidence for their effectiveness.



By enabling access to a wide range of **information needed to strengthen coping and adaptive capacities** among stakeholders at various levels. For example, through its “Journey” tool the Atlas guides users to a map showing where Ethiopian pastoralists live, and allows them to explore and visualize the stressors they face, including the lack of investments in human capital that can hinder their capacity to adapt or transform. This data can be used by governments and by resilience practitioners as a planning tool or to communicate to stakeholders.

The following are illustrative examples of the ways in which the Resilience Atlas is contributing to strengthen resilience attributes:



Resilience Buff Zone

THE RESILIENCE ATLAS & RESILIENCE ATTRIBUTES



Robustness

It provides decision-makers with an open-source, scalable, cloud-based technology platform that leverages big data for resilience investment/intervention planning and assessment.



Rapidity

It provides easily accessible information and visualization options, based on up-to-date datasets to inform decisions.



Learning

It enables users to explore specific data that is relevant to them and discover the answers for themselves. It also: examines and maps how different types of assets and the interplay among them affect the resilience of specific livelihoods; assesses the effectiveness of interventions and investments; and establishes baselines to measure progress on key indicators.



Scale

It integrates datasets at the regional, national and local scales, connecting themes and perspectives in order to provide decision makers with a more comprehensive view to inform decisions.



Diversity

It pulls together more than 60 data sets on 40 countries to provide a more comprehensive and diverse perspective of vulnerable developing contexts.



Redundancy

It brings together multiple disciplines, themes and experts to look at problems from multiple angles.



Equity

It enables open access to data to a wide range of users, facilitating a better understanding of important issues like climate change, flooding and drought impact to more people.

Key Lessons Learned

Data Access

Just as resilience building is unique to each context, data access is a unique experience for each user. Seeking to both convey and respond to this diversity, the Resilience Atlas provides users with “Journeys”—a curated pathway to explore different data layers and gain new insights into the resilience of particular systems and places. When accessing the data, users can decide on a specific geography and theme of interest, examine exposure of a particular system to different shocks and stressors, and consider the impacts on its vulnerability. In addition to facilitating data access by demonstrating how to use the Resilience Atlas, this approach encourages the user to explore the data further.



Data Assessment

Data integration and assessment are not an “end goal,” but a step in the right direction. In order for Big Data to play a role in resilience building, data analysis should be followed by data visualization and engagement focused on user needs. The Resilience Atlas integrates more than 12 terabytes of resilience data and summarizes outputs in user-friendly maps that are frequently refreshed as relevant datasets are released or updated by the original source to ensure clarity and applicability.





Data Application

In order to inform decision making, data needs to be timely and relevant. The cloud computing infrastructure of Amazon Web Services (AWS) provides the Resilience Atlas with the ability to automate processes as more data sets covering different trends become of interest to the community.

Data Actionability

User engagement is key to ensure the transition from data into action. Through a capacity-building workshop held with Madagascar government representatives in February 2017, the Resilience Atlas informed the design of targeted recommendations for the country's National Adaptation Plan (NAP). Stakeholders used the Atlas to identify regions where ecosystem-based adaptation (EbA) can address climate impacts in the water, agriculture, coastal/disaster risk reduction, forestry and biodiversity sector, and to categorize specific recommendations where EbA could alleviate the effects of climate shocks and stressors on beneficiaries. Integrating subnational datasets into the Resilience Atlas provided a platform for stakeholder discussion and familiarization with datasets across all sectors and informed participatory planning and assessment for the development of the NAP.

Key Enablers and Challenges



Enabling

Approaching Big Data as a two-way learning opportunity

The use of the Resilience Atlas in Madagascar allowed government users to identify gaps in the country's data, and it also allowed Conservation International to better understand how stakeholders use the Atlas to solve a problem, what types of data and functionality are most useful, and areas where further development or new data might be needed.

Challenging

Ensuring usability and future sustainability

The Atlas has proven useful for identifying ecosystem-based adaptation projects in Madagascar and South Africa, baseline assessments of Ethiopia and the Democratic Republic of the Congo (DRC), and for priority setting in Africa and Asia. These opportunities allow for maintenance and updates of the Atlas on a periodic basis. The team is currently working to develop a plan for longer-term sustainability, including interfacing with industry users around specific resilience challenges.

Challenging

Limited connectivity

The tool allows basic overlays of spatial data layers, freely available in a web browser. Constraints due to limited internet connectivity in some of the regions where Conservation International works proved challenging for capacity-building efforts. Enhancements of the Atlas to improve performance with limited connectivity is underway.

Enabling

Enabling the integration of user data

Resilience-building processes take place between and across scales. By striving to provide national, regional, and local-level data, the Atlas provides a more comprehensive view of vulnerable contexts, adding value to resilience thinking and programming options.

Enabling

Robust technical skills of the CI implementing team

Having a strong technical team that combined skills in remote sensing, computer programming and data management was key throughout the stages of design and implementation of the Atlas, in order to ensure the capabilities needed to manage a large-scale and highly diverse dataset.

Challenging

Integrating the use of a Big Data-based platform in decision-making processes

The tool is user-driven and therefore reliant on the user for successful interpretation of datasets and overlays. The Atlas provides journeys to walk users through data-driven insight as guidance. This has helped demonstrate to users how to use the tool, and to build confidence in the datasets. However, the integration of these tools as part of broader decision making requires time, capacity and further awareness.

Recommendations

Big Data is not only about large-scale applications. As the Resilience Atlas demonstrates, Big Data tools can also be used to better understand pathways of change at the national, subnational and community levels. It can help resilience practitioners gain new insights into cross-scale linkages and interactions, including the way in which global and local patterns and behaviours influence each other.

Future work in this field should help bridge the gap between large, medium and small datasets to provide a more holistic understanding of the impacts of shocks and stressors at multiple scales to strengthen resilience programming.

Private sector partners play a key role in the provision of a more holistic and up-to-date perspective on resilience-building efforts. The Resilience Atlas uses [Amazon Elastic Compute Cloud \(Amazon EC2\)](#) for processing and serving the data to users; at one time 120 servers were used during a usage spike. Amazon EC2 made it possible to do in only a few days what would have taken over a month. Innovative partnerships and alliances with private sector partners need to be explored as the role of Big Data in resilience building continues to evolve.

In resource-constrained developing settings, processes of data gathering, analysis and visualization should be followed by evidence-based prioritization. Big data for resilience tools should allow users to prioritize actions within and across all sectors, and to identify the most pressing interventions needed to better cope with and adapt to the impacts of shocks and stressors. The Atlas played this role in Madagascar, where stakeholders had the information needed to prioritize the most pressing actions needed for mitigating climate change within the country.

Big Data functionalities should be constantly evolving in order to increase its value to users. Examples include developing analysis features to allow users to perform simple calculations directly within the tool (for example mean temperature change in an area or areas covered by forest), as well as the ability to upload their own data layers to the Atlas in order to view it in conjunction with the curated set of layers already available in the tool.



Additional Information:

- [Resilience Atlas About, Map and Journeys](#)
- [Resilience Data Analytics Tool and the Cloud Help Humans Survive and Thrive](#)
- Conservation International and the Resilience Atlas: <https://www.conservation.org/projects/Pages/Resilience-Atlas.aspx>
- Madagascar Resilience Atlas: <https://madagascar.resilienceatlas.org/map>
- Global Resilience Partnership: <https://atlas.resilienceatlas.org/map>
- <http://www.globalresiliencepartnership.org/maps/>

This case was prepared by the author with contributions from Alex Zvoleff and Monica Noon, Conservation International.



Combining Small and Big Data to Enhance Resilience in Malawi

An initiative of the Netherlands Red Cross 510 data initiative and EU European Commission Humanitarian Organization

The 2015 floods marked one of Malawi’s worst natural disasters in its recent history. The President declared a state of emergency, as some of the poorest districts were severely impacted by overflowing rivers, damaged infrastructure, displacement and human loss. According to data from the UN’s Office for the Coordination of Humanitarian Affairs (OCHA), more than 19,000 households were displaced due to the flooding, which also resulted in crop loss, food insecurity and health impacts. In Southern areas such as Zomba, Chikwawa and Nsanje, these impacts exacerbated pre-existing vulnerabilities linked to the lack of economic, human and physical resources.

For a country that depends highly on subsistence farming and has a relatively dry—and strongly seasonal—climate, the heavy rains had a profound impact on local livelihoods, challenging the ability of local institutions and community stakeholders to cope effectively with climate-induced shocks. As the flooding spread through more than half of the country’s districts, decision makers had to operate with incomplete data, in addition to short timeframes, political pressures, media coverage and lack of access to information. The disaster evidenced the need for more data-driven decision making to enable at-risk populations to absorb the impacts, adapt and potentially transform in the face of shocks.

The Post Disaster Needs Assessment (PDNA) conducted in 2015 by the Government of Malawi identified resilience building as a key component

of the reconstruction and recovery process, acknowledging the need to go beyond short-term responses, and adopt long-term solutions to address vulnerability and risk. Among the main lessons identified in the PDNA is the need to improve both the availability and the management of (spatial) data and information to inform and guide decisions.

The ECHO Enhancing Resilience in Malawi (ECHO ERIM) project was developed to foster the effective design of Disaster Risk Reduction (DRR) and mitigation strategies, as well as disaster preparedness and response planning. With funding by the EU European Commission Humanitarian Organization, this initiative uses Big Data to complement and strengthen traditional vulnerability and capacity assessments, which are key to ensure evidence-driven approaches to resilience.



Resilience Snapshot

ECHO ERIM & CORE RESILIENCE QUESTIONS

RESILIENCE WHERE?

Malawi

RESILIENCE OF WHAT?

At-risk communities in flood-prone areas in Zomba, Chikwawa and Nsanje

RESILIENCE OF WHAT?

Flooding

RESILIENCE FOR WHAT PURPOSE?

To improve local preparedness and response capacities to reduce vulnerability and strengthen long-term community resilience.

RESILIENCE HOW?

It empowers communities by making them risk-informed and building ownership in the identification and development of solutions to increase their resilience. This involves increasing the capacity of disaster-prone Group Village Heads (GVHs) in Zomba, Chikwawa and Nsanje on community-based disaster preparedness structures, response and early-recovery mechanisms.

Understanding Vulnerability Through Digital (and Non-Digital) Datasets

The Vulnerability and Capacity Assessment (VCA) process was developed to help communities become more resilient by assessing the hazards that affect them and identifying priorities and appropriate measures to minimize their potential impact. Based mostly on participatory tools for data collection (e.g., community mapping, focus group discussions, transect walks), the VCA provides a toolkit for community-based programming.

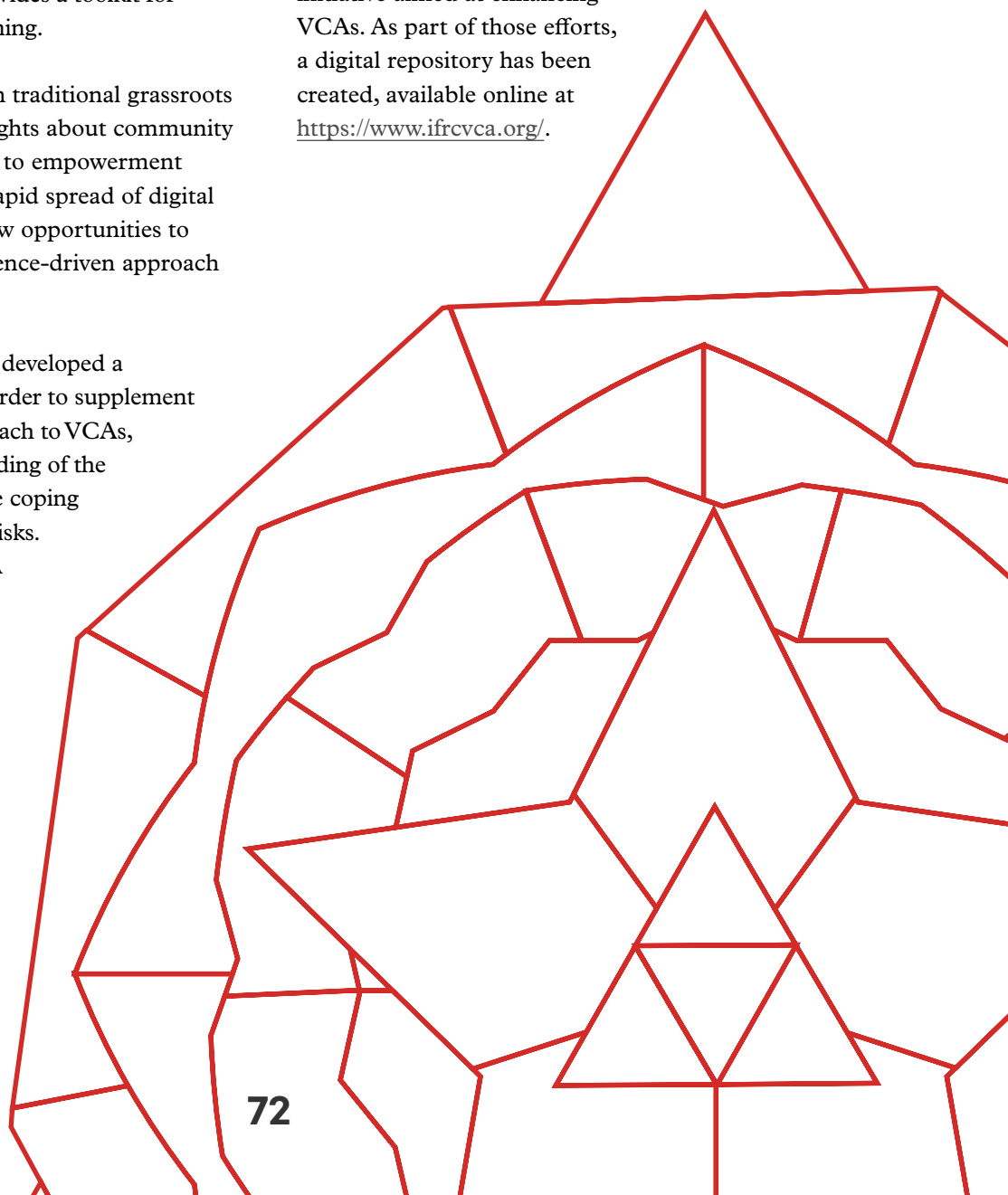
While data gathered through traditional grassroots methods yields valuable insights about community perceptions and contributes to empowerment and awareness raising, the rapid spread of digital technologies is providing new opportunities to achieve a more holistic evidence-driven approach to resilience building.

The ECHO ERIM initiative developed a digitally supported VCA in order to supplement the traditional/manual approach to VCAs, and gain a deeper understanding of the levels of vulnerability and the coping capacity of communities to risks.

The digitally supported VCA transforms some of the VCA tools through statistical data and GIS analyses. For example, paper-based participatory community maps are now prepared using a collaborative digital

mapping approach. This approach provides a more complete picture of local vulnerabilities, as well as mitigation and response measures that can be taken.

Digitally supporting or transforming VCAs is part of a larger International Federation of Red Cross and Red Crescent Societies (IFRC) initiative aimed at enhancing VCAs. As part of those efforts, a digital repository has been created, available online at <https://www.ifrcvca.org/>.



Tech Buff Zone

ECHO ERIM & THE V'S OF BIG DATA

BIG DATA VOLUME

TBs

BIG DATA VELOCITY

Periodic (e.g., risk assessment updates) and near-real time (e.g., impact-based forecasts, river floods, flash floods)

BIG DATA VARIETY

- **Risk assessment:** the INFORM Risk Index was developed by EU Joint Research Centre (EU JRC and United Nations Office for the Coordination of Humanitarian Affairs (UN OCHA) and is used to calculate the Community Risk Assessment by multiplying *Vulnerability x Hazard & Exposure x Lack of Coping Capacity*. It uses data in diverse forms (shape files, excel tables, multimedia etc.) and from different sources (satellite images, field surveys, census, hydrological modelling etc.) to calculate a composite risk index. Multiple data sources of different formats are collected (e.g., through Python-based scraping of government-websites), automatically cleaned, and integrated into a PostGIS-database. If data is missing:
 - a) For exposure data: Missing Maps “mapathons” are organized to trace relevant features (such as houses, roads) on satellite images and to enrich OSM data. Garmin VIRB cameras were also used to document field visits. The data collected by the cameras was uploaded to [Mapillary](#) and OpenStreetMaps, contributing to the open “street view” images of the world—these were the first street view images made for Malawi.
 - b) For vulnerability data: Big Data Analytics can be used to determine Proxy-indicators: methods are developed to predict vulnerability and poverty purely using map-based (OpenStreetMap) features such as remoteness. This allows the creation of a global measure of these variables without having to survey the entire world.
- **Impact-based forecasting** goes one step further than the risk assessment and uses short-term instead of long-term hazard forecasts as well as historical impact data. **Machine learning** uses this as input data to predict where the impact will be highest (output). Models used are CART Decision Tree, Conditional Inference Tree, CART Random Forest and Conditional Forest to predict flood impact.
- **Dashboard visualizations:** All the results of both the risk assessments and impact-based forecasting are presented in a Javascript-based online dashboard, which plugs into the PostGIS-database and uses the most advanced techniques to [visualize results](#).

BIG DATA VERACITY

For the Community Risk Assessment a Data Sets Preparedness Index is developed in order to measure the Completeness, Accuracy and Reliability and Recency (i.e., is the data out-dated or still relevant) of the data on each risk indicator. It is an ongoing and iterative process to improve the score by continuously scouting for better open data sets or by collecting data as part of the project if there is a clear data gap. Data validation is done through triangulation of different sources, and by consultation with (local) experts and communities in the flood-prone areas.

How Does ECHO ERIM Build Resilience?

Data plays a crucial role in the processes of resilience building. As the experience of ECHO 2 in Malawi has demonstrated, the emergence of digital data offers an opportunity to complement and strengthen decision making, empower local stakeholders, and broaden the understanding of local vulnerability and adaptation priorities. The initiative is helping to build coping and adaptive capacities by:



Enhancing the data preparedness of vulnerable communities in Malawi, strengthening their ability to cope more effectively in the event of natural disasters and other shocks. For example, the mapping capabilities support the identification of safe evacuation routes which can be used by communities to access temporary evacuation areas when an alert of a potential hazard is triggered. Improved information on access to evacuation sites, including travel time and road conditions, supports the logistical planning involved in developing and implementing a response.



Improving the community's understanding of the levels of vulnerability in at-risk areas through more complete, accurate, timely data with geospatial attributes; increased spatial heterogeneity of household-level vulnerability. The digital VCA contributes to community and district action and contingency plans as concrete instruments of disaster preparedness and response.



Facilitating the identification of areas that exacerbate the impact of hazards at the community level, and that can be addressed through long-term adaptation and preparedness measures (e.g., reforestation and riverbank enforcement).

The following examples illustrate the way in which ECHO ERIM helps build flood resilience in Malawi by strengthening key resilience attributes.

Resilience Buff Zone

ECHO ERIM & RESILIENCE ATTRIBUTES



Robustness

It strengthens the decision-making capacity of local stakeholders through the availability of more comprehensive, context-appropriate dataset that can be easily accessed to inform and prioritize disaster response areas of focus/actions.



Rapidity

It fosters data preparedness, allowing local stakeholders to get more accurate data on forecast hazards and identify who was affected in the event of a disaster, and importantly, exactly where they are located. Improved top down and bottom up information flows between the National, District and community structures supports timely preventative action and prompt, effectively targeted responses.



Scale

It creates methods, dashboards and tools that can be replicated in other countries, including the Community Risk Assessment dashboard, and linked to this, it develops globally accessible databases, such as the [global repository](#) of VCA reports with allowing users to upload, search for and access VCA reports and Plans of Action produced worldwide. The platform includes more than 150 documents from 45 countries, collected over the last 14 years. Scale is also strengthened by enhancing grassroots data with open and big data.



Diversity

It combines open and big data with data collected through traditional methods (e.g., field surveys conducted by enumerators) in order to ensure a more comprehensive understanding of the local vulnerability context.



Redundancy

It complements Big Data sources with data collected through the VCA process globally, through the VCA platform. The platform allows National Societies to have a historic repository of their work and to access relevant information for longer-term monitoring of risks and vulnerabilities or for situational awareness in case of an emergency.



Equity

It fosters the use of Big Data complemented by grassroots data collection to ensure stakeholder engagement and ownership, as well as through the empowerment of communities to identify and develop solutions to increase resilience.



Learning

It trains local enumerators on data collection techniques, including the use of [new types of equipment/software](#) such as Portable Open Street Map, Mapillary, and Open Data Kit.

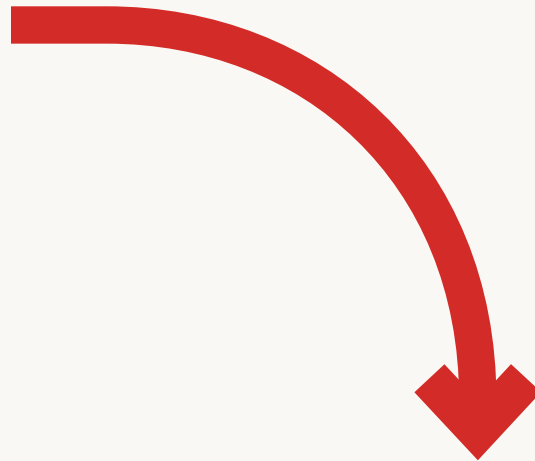


Key Lessons Learned

Data Access

The creation of a data ecosystem in which different stakeholders open up and share their data with one another is fundamental to ensuring access. In cooperation with the [GPSDD project on data for SDGs](#), ECHO ERIM organized a series of workshops to strengthen the data ecosystem in Malawi and to assess the technical, legal and commercial barriers to data sharing. The process of data collection and sharing was discussed with Malawian government institutions and with the humanitarian sector in order to gain an in-depth understanding of local needs and to ensure buy-in.

ECHO ERIM also fosters data accessibility by making the VCA reports available online using simple formats and maps to illustrate priorities, including [visualization tutorials](#). The project is providing smart phones to Early Warning and Response Teams to support routine monitoring of river levels and the rapid dissemination of alerts from the national and district structures to the community-based teams. Because the methods used for Big Data analytics rely on sufficient filling of Open Source Maps (OSM), “[mapathons](#)” are continuously organized. Stimulating the generation of Big Data is a crucial component of digitization.



Data Assessment

Disaster impact information is currently gathered by teams that go into the affected areas to conduct interviews and review infrastructure damages, so that priority areas can be identified. This process is time consuming due to logistics, safety constraints and workload. The result is often subjective when political preferences and media intervene. Machine learning techniques can play a valuable role in forecasting local needs and strengthening disaster preparedness by avoiding those challenges. Collaboration with local stakeholders is key to getting the right input data for the machine learning models. ECHO ERIM used [advanced data analysis](#) to forecast the amount of help that Traditional Authorities (administrative areas) in Malawi would need in case of a flood, including the identification of key [influential factors](#).

Data Application

Collecting and analyzing data only makes sense if it is used as part of decision-making processes. One of the key decision-making processes ECHO ERIM aims to support is the prioritization of areas and households for DRR or response interventions. For decision makers operating in low-resource environments, the ability to prioritize areas of focus based on robust evidence can have a significant impact on taking the right actions to increase their resilience. ECHO ERIM conducts Community Risk Assessments that are based on open data and offer nation-wide coverage. In Malawi, the risk assessments were used in selecting priority areas for project interventions.

Data literacy has also been identified as a fundamental component to ensuring the application of data in practice. As part of ECHO ERIM, a data team was recruited within the Malawi Red Cross Society, consisting of GIS, data and disaster risk experts. This was key to increasing data capacity within the Red Cross, as well as in positioning digital transformation in the organization's agenda. The Netherlands Red Cross and the Malawi Red Cross Society data team provided trainings to enumerators and trained the trainers, so that the approach could be scaled-up and replicated.



Data Actionability

Financing is at the core of actionability. ECHO ERIM is working on fusing different data sources (i.e., historical satellite imagery, social protection beneficiary lists, Open Street Map data, and forecasts) to identify beneficiaries that that could be targeted during an “Early Action” (i.e., cash transfer) from the moment flood forecasts exceed the danger level to when the actual floods arrive. This impact forecasting component is aimed not only at predicting where the floods will take place, but in particular, at what they will do. When available with sufficient lead time (i.e., 3 to 6 days), early actions and preparedness can be triggered.

Key Enablers and Challenges



Enabling

Matching data and information needs

Available data needs to match information and knowledge needs in order to lead to an enhanced situational awareness and enable adequate decision making. This is achieved through community engagement and collaboration in the development of VCAs.

Challenging

Balance data quality, relevance and variety

This challenge refers to the need to strengthen the role of Big Data in local decision making by integrating diverse types of data, including meteorological data, while ensuring data relevance and quality.

Challenging

Data aggregation across scales

Working across scales is key in resilience building. While linking data from VCAs to the Country Risk Assessment (CRA) overviews can provide a more complete, cross-scale perspective on vulnerability, combining patchy, highly specific data with country-wide data at a higher aggregate level is a challenge.

Enabling

Combining Big Data with traditional data collection approaches

A comprehensive situational overview can't be achieved solely by monitoring social media or analyzing data imagery. Integrating grassroots data collected through qualitative methods (e.g., focus groups, interviews) can provide valuable insights about the local context to complement Big Data/digital sources. The success of this “hybrid” approach also involves empowerment of local stakeholders. In the case of digital data, this has included training on [OpenDataKit \(ODK\)](#) and [OpenMapKit \(OMK\)](#): tablet- or smartphone-based applications to conduct digital surveys in the field.

Enabling

Robust approach to data responsibility and privacy

Ethical data collection and storage are crucial to ensure a responsible and sustainable impact on resilience. ECHO ERIM implements a variety of mechanisms to safeguard data privacy and security. They include consulting with and seeking permission from the village chief for the data collection, avoiding the collection of personally identifiable data or any data about the household composition and vulnerabilities, and processing the photos collected for Mapillary through [computer vision technology](#) to anonymize faces and licence plates.

Challenging

Interoperability and harmonization of datasets

There is a high level of heterogeneity in data sets due to the multitude of procedures and stakeholders involved in disaster response. This lack of coordination can hamper the effectiveness of data as part of decision-making processes.


Recommendations

Working with vulnerable people in developing countries often involves the adoption of a “hybrid” approach to Big Data. Responding to local needs and available resources may require combining data from both secondary/open data sources with primary data (e.g., field surveys, rain or water level gauges, aerial imagery with drones and other remote sensing technologies). Leveraging widespread low-entry information sharing platforms such as WhatsApp supports the rapid dissemination of information across a range of contexts, facilitating almost instantaneous communication of key information from data-rich environments to remote communities.

Acquiring relevant, accurate, and comprehensive data is an iterative rather than a linear process. In the immediate aftermath of a disaster, decision-makers face short timelines—and high levels of uncertainty—when making decisions. Data approaches should address short-term information gaps but should also be complemented and strengthened over time to respond to emerging needs.

Building local capacities to access, analyze and use Big Data is essential to avoid widening the digital divide that exists between developed and developing countries. Building capacity is key to ensure local ownership, data privacy and security, and ultimately for the sustainability of data’s role in decision-making processes.

Ensuring stakeholder inclusion in the data cycle is essential to address information gaps, and to ensure the timeliness and data granularity required to inform decisions. Big Data approaches offer new forms of engagement for stakeholders at the local, national and international levels (e.g., international volunteer networks), contributing to more robust vulnerability baselines and assessments. Multi-scale networks and collaboration should be explicitly considered as part of the design and implementation strategies of future initiatives in this field.



Using data in a responsible manner is vital to ensure the applicability of humanitarian principles and to do no harm. While legal instruments on data protection are an important step to enhanced transparency, data responsibility takes into account ethical considerations that go beyond compliance. Responsible use of data means bearing in mind the consequences the use of data could have on vulnerable people around the world and taking measures to avoid putting individuals or communities at risk.

Recognizing that the responsible use of data will shape the humanitarian ecosystem, the Netherlands Red Cross 510 team developed a policy to incorporate principles for the responsible use of data in the daily work of the organization. This policy can serve as a reference for other organizations working on data-driven solutions for humanitarian aid.

Additional Information:

- <https://www.510.global/data-preparedness-in-malawi/>
- IFRC Vulnerability and Capacity Assessment site: <http://www.ifrc.org/vca>
- <https://dashboard.510.global/>

This case was prepared by the author with contributions from Marc van den Homberg, The Netherlands Red Cross 510 data initiative, and Mark Powell, Red Cross Flanders.

Repurposing Mobile Technology to Build Resilience

Mongolia's Advanced Weather Information System (AWI)

An initiative of Mercy Corps



Over the past 20 years, herder communities in Mongolia have witnessed dramatic changes in their environment. One of the most significant has been the increasing magnitude and frequency of dzuds, or slow-onset disasters characterized by hot dry summers followed by blistering winters, which have killed more than 20 million livestock since the year 2000. Dzuds are often preceded by drought, resulting in insufficient pasture and hay production in the summer, and negatively impacting the livelihoods of the more than 300,000 households that depend on livestock for food, water, income and transportation.

For herders in remote rural areas, dzuds have far-reaching consequences. They can limit access to health care, education, and government support. Many households resort to minimizing food intake and fuel consumption to preserve winter stores, while severely affected households leave the agricultural sector and migrate to urban or peri-urban areas in search of employment. Dzuds also take a toll on the health and well-being of herder communities, increasing child mortality, stress-related suicides and adult illnesses.

Climate change, among other shocks and stressors, intensifies the impact of dzuds in Mongolia, and communities are more vulnerable than ever to their effects. Yet, as recently as 2015, most of them lacked the information and knowledge products needed to build a sufficient line of defence against natural disasters.

While most herders have access to radio and television broadcasts, neither provided the hyperlocal weather information they needed to make critical

decisions—i.e., when to shear sheep, harvest hay, or go to the market. Mobile phones, on the other hand, have the potential to close the information gap. Approximately 95 per cent of the rural Mongolian population uses mobile phones, making text messaging a convenient and cost-effective way to access information.

In 2016, Mercy Corps Mongolia, with funding from USAID/OFDA, developed an SMS platform—the Advanced Weather Information System or AWI, which translates to “get” in Mongolian—repurposing existing technology for local communities through on-demand weather forecasts and pasture information. Data is pulled from a variety of open data sources, in real time, helping herder households to more effectively prepare for and respond to the impact of natural disasters.

Resilience Snapshot

AWI & CORE RESILIENCE QUESTIONS

RESILIENCE WHERE?

Mongolia

RESILIENCE OF WHAT?

Herders and herder communities

RESILIENCE OF WHAT?

Slow-onset natural disasters

RESILIENCE FOR WHAT PURPOSE?

It strengthens rural livelihoods and well-being, increasing the district-level capacity for emergency response and recovery throughout Mongolia.

RESILIENCE HOW?

It provides localized weather and pasture information in real time to inform decision making of herder households.

AWI

Building Herders' Resilience Through Mobile Phones

AWI was launched in Mongolia's most disaster-prone communities in order to provide weather forecasts, forage information, and emergency alerts down to the sub-district level, using a technology already widely adopted: the mobile phone. Users can submit an information request to the AWI platform via text message (SMS). Once they provide their zip code, users can choose between a 3- or 6-day real-time weather forecast or a local forage and emergency report.

When the platform receives the request, the system fetches real-time information from a cloud-based server, plugs that information into a text message and returns it to the user, who can expect a response within two to five seconds. In cases in which the user is out of the mobile network's coverage when making an information request (e.g., in an area with poor reception or limited connectivity), AWI sends a message as soon as the user reconnects to the network. Each data point is pulled from a different open source database, covering topics that are crucial for the resilience of rural livelihoods



Tech Buff Zone

AWI & THE V'S OF BIG DATA

BIG DATA VOLUME

30 GB

BIG DATA VELOCITY

Real time

BIG DATA VARIETY

- Weather information – <https://darksky.net>
- Pasture information – <http://www.mongolialews.net/>
- Emergency warning information – National Emergency Management Agency of Mongolia / Mongolian National Agency of Meteorology and Environmental Monitoring

BIG DATA VERACITY

The data collected is verified through:

- Each data point was tested repeatedly throughout AWI's development.
- Mercy Corps is working with National Agency for Meteorology and Environment Monitoring to validate the accuracy of the weather information sourced from <https://darksky.net>.





How Does AWI Build Resilience?

Effective access to and utilization of relevant data is key to ensuring that Mongolia's livestock sector is resilient enough to withstand the impact of economic shocks and stresses and, consequently, to driving a sustainable, multisectoral pattern of economic growth. AWI helps build coping and adaptive capacities by:



Strengthening the **coping and adaptive capacities** of herder communities by connecting them to real-time weather forecasts, pastureland data and emergency alerts that enable them to protect their livestock and better manage their livelihood.



Improving the **emergency response and recovery ability** of herder communities through a messaging platform that leverages existing mobile technology, providing relevant and timely information on disaster mitigation and prevention.

The following examples illustrate the way in which AWI is contributing to build resilience in Mongolia, through key resilience attributes:

Resilience Buff Zone

AWI & RESILIENCE ATTRIBUTES



Robustness

It improves institutional capacities, particularly of the National Emergency Management Agency (NEMA) of Mongolia, to better prepare for and respond to natural disasters, establish new partnerships, and take ownership of the AWI platform.



Self-organization

It provides herders with the opportunity to plan their daily livestock grazing plans, including where to graze, based on daily weather conditions (e.g., when to start long-distance grazing activities, sheering sheep wool, combing goat cashmere and cutting hay).



Learning

It enables access to new information relevant to local livelihoods, strengthening the users' skills to plan and improve the economic viability of livestock herding and production.



Equity

It provides fast and easy access to relevant information to low-income herders and herder communities and ensures that the service provision is affordable and sustainable. The tariff to send messages to the AWI system is USD 0.02, which also covers the cost of the corresponding response. The public access phone number is also exempted from the monthly service fee by Mobile Operators as part of their corporate social responsibility.



Scale

It continuously grows in terms of both size and scope, expanding the service's coverage to additional districts in different provinces of the country



Rapidity

It allows fast access to weather information and emergency reports, fostering the prompt implementation of diverse risk-mitigation strategies in herding communities (e.g., defer travel to/from an at-risk location, keeping livestock close to campsites instead of grazing in distant pastures) based on real-time information.



Flexibility

It provides information that can strengthen the planning process of not only herders, but also a wide range of stakeholders (e.g., by soum doctors planning rural emergency visits; soum rangers patrolling nature reserves; electricians planning repairs of broken electrical lines in the countryside).

Key Lessons Learned

Data Access

Data accessibility is highly context-specific. In remote parts of Mongolia, 3G/4G data access through mobile devices is often limited by poor connectivity, lack of network coverage, and the high cost of service delivery. AWI ensures data accessibility through the use of a simple text messaging system that does not require 3G or 4G data for the delivery of real-time information. Partnerships are also key to ensure data accessibility. In October 2017, Mercy Corps facilitated agreements between government stakeholders and mobile service providers in order to (a) develop a public access telephone number to maximize the impact and outreach of AWI while keeping the service affordable for low-income households, (b) enable users to send and receive an unlimited number of messages, (c) expand service coverage and (d) improve service delivery.



Data Assessment

Robust assessments are enabled by trustworthy data that is easily understood by its users. In the AWI platform, this is achieved through the high accuracy of weather information, as well as finer spatial resolution than other forecast information services. The project team is currently developing an online dashboard to measure service usage throughout the calendar year, identify patterns, and mine user data down to a sub-district level. This data will help assess user satisfaction and target promotions in under-performing districts.





Data Application

Data applicability requires capacity. The implementation of the mobile messaging platform builds on Mercy Corp' capacity-building activities on risk management in targeted communities, including a training workshop designed using an international set of livestock emergency guidelines and standards (LEGS), a best practices book based on local experiences, as well as collaborative approaches to disaster plan development in herder communities.

Data Actionability

An important element of any initiative is learning from impact. Understanding the way in which data translates into actions that build resilience plays a key role in that process. Data actionability is monitored and measured as part of AWI's Monitoring and Evaluation component through qualitative impact assessments conducted on a semi-annual basis and on a custom dashboard that tracks quantitative service usage, identifies trends, and enables Mercy Corps to make changes to meet the wants and needs of its users. The AWI system is currently used by herder households in 209 out of 331 districts in Mongolia, in 17 out of its 21 provinces. Since 2016, more than 12,000 users have consulted AWI to inform decision-making processes: herders to graze their livestock; farmers to harvest their crops; and emergency responders to determine when and where to evacuate families in the event of a snowstorm.

Key Enablers and Challenges



Enabling

Ensuring low-cost, relevant services for sustainability

Despite initial concerns that herder communities could not afford the USD 0.02 per transaction price tag, an impact assessment conducted in 2017 indicated that 34 per cent of users have used the service three or more times and 8 per cent have used it 10 or more times. This indicates that herders and herder communities are both willing and able to pay for information that improves their livelihoods.

Challenging

Transferability of the platform to the Government

Transferring a platform to ensure ownership and sustainability is a complex process. It involves financial resources, technical expertise, capacity building, in addition to strong partnerships. The primary challenge faced when discussing the transfer of the system were the operational costs. This challenge was addressed through donor funding, and a successful negotiation with mobile operator companies.

Challenging

Data curation and quality verification of open source data

Mercy Corps is already in discussions with the National Agency for Meteorology and Environment Monitoring to validate the accuracy of the weather information sourced from <https://darksky.net>. The National Agency for Meteorology and Environment Monitoring is the official weather forecasting agency of Mongolia with observation stations across the country.

Enabling

Training strategy informed by continuous assessment

AWI was originally designed for the benefit of herders and their families, but an impact assessment conducted 6 months after launch indicated that farmers, veterinarians, and emergency personnel also made frequent use of the service. Continuous assessment of impact is key to inform training strategies and target adequate stakeholders.

Enabling

Building new partnerships across sectors

Mercy Corps is collaborating with two open data source providers, as well as with the National Emergency Management Agency of Mongolia, who agreed to take ownership over the system in 2018. It has also facilitated partnerships with mobile services providers to lower costs and improve service coverage and quality.

Challenging

Securing resources to develop and launch the system

Building and introducing the system required significant technical and financial resources, which were obtained through funding from USAID/OFDA and a new grant through ECHO in partnership with the NGO People in Need.

Recommendations

In order to ensure transformative impact, the use of Big Data needs to be sustainable. In low-income and marginalized areas, Big Data approaches should focus on creating sustainable solutions, rather than developing technologically advanced but short-lived initiatives. By providing a simple, yet relevant technological solution, AWI can be easily maintained—and built upon—by government stakeholders going forward.

Data relevance is the basis for local adoption. AWI was created in response to a country-wide need for real-time, on-demand weather information by vulnerable herding communities and other stakeholders affected by the impact of slow-onset natural disaster. The early identification of that demand and of local priorities was key to informing the design of the platform, and to identifying adequate open data sources.

Think about scale and build a platform that can grow with your program. Even though the first iteration of AWI was limited in scope and scale, Mercy Corps created an open architecture that provides an opportunity to scale up coverage, add new features and adjust the services to changing user needs. What started as a mobile weather service for disaster-affected areas now has the potential to provide information for disease mapping and snow depth, pasture carrying capacity and meat market prices, among others, at a national level.

Building resilience through Big Data requires the continuous exploration of novel approaches to address both pre-existing and emerging challenges. In rural parts of Mongolia, there is still the need to improve connectivity through incentives and partnership building with the private sector. These processes can be facilitated by development stakeholders through cross-sectoral collaboration.



Additional Information:

- Mercy Corps: <http://mercy Corps.org.mn/beta/index.php/mn/>

This case was prepared by the author with contributions from Bilguun Batsukh, Eliot Levine and Enkhtuya Buyandalai, Mercy Corps.



Unlocking Big Data's Potential to Strengthen Farmers' Resilience

The Platform for Big Data in Agriculture

An initiative of the CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS)

In 2014, 170 Colombian rice farmers avoided a staggering USD 3.6 million in losses after following the advice of their national association, Fedearroz, not to plant the crop in the first of two annual growing seasons. Advanced computer models predicted a drought in the Caribbean department of Córdoba, which led Fedearroz to conclude that farmers in some regions could save themselves from crop failure by not planting at all.

The availability of free and open access to large amounts of crop and weather data—combined with data mining approaches—enabled researchers to spot the main limiting factors of crop productivity at a site-specific scale, combine it with seasonal climate predictions, and get the information to farmers in time to inform their planting decisions.

The rapid growth in processing power and global connectivity means that huge amounts of data can now be collected, shared and analyzed faster than ever before, and most importantly, can be turned into recommendations to inform the decisions of farmers and policy-makers.

The increased access and use of Information and Communication Technologies (ICTs) is redefining the way in which knowledge is managed and

decisions are taken. Yet many rural households in Africa, Asia, and Latin America and the Caribbean are still behind in the ICT revolution. Despite the ubiquity of technologies such as mobile phones, many farmers lack access to the kind of information they need to produce more food, more sustainably, and to respond and adapt to the impacts of climate. Most agro-climatic or food security information products are not tailored to farmers’ needs—they lack the resolution, frequency or the type of information necessary to be actionable at local levels.

Harnessing the potential of Big Data, CGIAR developed the [Platform for Big Data in Agriculture](#) seeking to enable the development sector to embrace data and other digital technology approaches to solve agricultural development problems faster, better and at greater scale.

Resilience Snapshot

THE PLATFORM & CORE RESILIENCE QUESTIONS

RESILIENCE WHERE?

Global, with a focus on agricultural challenges of Africa, Asia, Latin America and the Caribbean

RESILIENCE OF WHAT?

Farmers

RESILIENCE OF WHAT?

Climate variability and change

RESILIENCE FOR WHAT PURPOSE?

Strengthen food security and improve farmers’ well-being

RESILIENCE HOW?

Enabling the collection, analysis and delivery of actionable information to inform decision making of farmers and policy-makers

A Disruptive Take on Rural Resilience Building

Big Data analytics is an emerging discipline for the agriculture development sector. The Big Data Platform emerged in response to the need for a fundamental change in the way in which farmer organizations and their members operate and make decisions, and ultimately build resilience to climate impacts, pest and disease outbreaks and land degradation. It provides a novel approach to bridge agricultural science, applied research and data sources, and development practice.

Building on the extensive applied research experience and global networks of CGIAR, the Platform offers novel ways to organize and disseminate open data on

agriculture, to develop innovative ideas fostering the role of information technology in agricultural resilience, and to demonstrate the power of Big Data analytics through inspiring projects that bring together a variety of stakeholders.

The Platform cuts across all CGIAR Research Programs, and actively collaborates with the Research Program on Climate Change, Agriculture and Food Security (CCAFS). In Latin America, the joint action of CCAFS and the Big Data Platform in the area of site-specific agriculture and climate services has helped thousands of farmers better cope with climate variability.



Tech Buff Zone

THE PLATFORM & THE V'S OF BIG DATA

BIG DATA VOLUME

More than 60 TB of weather data, about 1 GB of on-farm data (80,000 cropping events from a wide range of both crops and countries), more than 100 GB of satellite imagery.

BIG DATA VELOCITY

Batch and periodic

BIG DATA VARIETY

- [Forecast web platform](#) to integrate information analysis and delivery: is the central platform where monthly agro-climatic bulletins are published, and where up-to-date monthly forecasts and management recommendations are produced and made publicly available
- [Site-specific agriculture web platform](#) to collect information from commercial production experiences, analyze data with new methods and generate information on site-specific limiting factors
- [AEPS-App](#), a tool for data collection to implement Site-Specific Agriculture at farm level. It allows data capture of crop management practices for rice, maize and beans.
- [RClimTool](#) allows going from raw observed weather data to knowledge on local weather conditions.
- Crop models, including the Oryza_v3 (rice) and DSSAT (maize, bean) models, are used to simulate crop growth under varied management and climate forecast scenarios.
- Climate prediction models including statistical (Climate Predictability Tool, CPT) and dynamical models are used to produce seasonal climate outlooks on a monthly basis.

BIG DATA VERACITY

The data collected is verified through feedback provided by farmers and technicians in workshops, meetings and Local Technical Agro-climatic Committees.

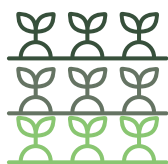


How Does the Platform Build Resilience?

The Platform for Big Data in Agriculture can play a key role in bridging scientific research and practice, and in ensuring that data translates into better-informed, more resilient actions. At local and regional scales that means farmers and farmer associations are adapting to the challenges posed by climate change, variability and land degradation. The Platform can strengthen coping and adaptive capacities by:



Increasing the capacity of farmers' associations to plan for and respond to the impacts of shocks and stressors through informed decisions based on context-appropriate scientific data. The Platform can also contribute to institutional robustness to climate change and variability impacts, as farmer organizations are able to include forecasting and site-specific management in their strategic business plan.



Strengthening the ability of farmers and farmer's associations to learn about and improve adaptive practices (e.g., determining which crop varieties work best within the context of climate variability), to establish and broaden inter-scale linkages (e.g., contact with local/regional organizations and a broad network of researchers), and increase the flexibility of decision-making processes (e.g., through continuously updated seasonal agro-climatic forecasts).

The following are illustrative examples of ways the Platform can strengthen key resilience attributes:

Resilience Buff Zone

THE PLATFORM & RESILIENCE ATTRIBUTES



Robustness

It leverages partnerships and provides access and training on the use of novel tools for data collection, curation, analysis, and delivery, thus increasing data quality, as well as the effectiveness and efficiency of farmer organizations and public institutions working with the agricultural sector.



Self-organization

It works in close collaboration with farmers and farmer organizations, providing evidence-based research to strengthen decision-making processes (e.g., growers' associations, meteorological institutes). This empowering approach contributes to the replicability and sustainability of the initiative.



Learning

It provides computer models, ICT tools, database structures and methodologies with accompanying curricula (training courses) and tutorials with open-access licenses to empower producers' organizations and public institutions to use them in their agricultural activities. Also meets with local stakeholders to discuss findings, and draw lessons. The formation of communities of practice (CoPs) will also contribute to learning on how best to apply cutting-edge data tools for agricultural development.



Scale

It broadens access to modelling tools to improve predictions, from the regional to the local levels. For instance, information accessed by meteorological services through modelling tools are fed into stakeholder-based approaches by more than 10 local technical agro-climatic committees.



Diversity

It introduces Big Data methodologies and machine learning—methods that are still rarely used in agriculture in regions such as Latin America—as well as software for seasonal climate forecasting (climate predictability tool, or CPT) to broaden and diversify the information base available to inform decisions.



Equity

It fosters an approach to Big Data based on farmers' needs and works collaboratively with farmers and farmers organizations towards their empowerment. In Colombia, the International Center for Tropical Agriculture (CIAT) designed a work plan together with the governments and the producer associations, so that the research could be effectively applied to the need of growers in a wide range of socioeconomic and environmental conditions.

Key Lessons Learned

Data Access

Unlocking the potential of Big Data is not only about making data discoverable, but also about making it accessible so others are able to reuse it. The Platform fosters data accessibility by organizing data so datasets are findable, accessible, and interoperable so they can be used increasingly in Big Data analytics. For CGIAR, data access is closely linked to understanding the “data demand.” This involves understanding farmers’ information needs (e.g., which information, in which formats, delivered through which channels) in order to truly empower them and their organizations with Big Data. A key success factor has been to work *with* the farmers, not for them.



Data Assessment

The assessment of Big Data should enhance analysis and forecasting capabilities, both of which are crucial for the agricultural sector to achieve resilience. The Platform uses scripts for Big Data analysis and for climate forecasting. These tools allow analysis of on-farm data to investigate climate and management limiting factors to crop productivity. Crop-climate forecasting scripts allow farmer organizations and the National Meteorological Offices to efficiently implement seasonal climate forecast model configurations, to automate large numbers of climate forecast model runs (for example, for many localities), and to connect climate forecasts with crop simulation models. Scripts are accompanied by tutorials and short training courses to foster use.



Data Application

Effective data application requires bridging science and practice. Building a common language with the users (e.g., individual farmers and farmers organizations) is key to be able to work effectively with farmers and farmer organizations. Data curation is also crucial for credibility among users and application in the field. The Platform places high emphasis on managing, structuring, organizing, and disseminating data effectively among agricultural stakeholders. This requires awareness about their specific needs, as well as monitoring and evaluation of the use of information and its benefits to farming households and farmer organizations to ensure that the data is used to inform decision making.

Data Actionability

Relevant data is actionable data. Involving the right set of partners since the inception of the initiative has been fundamental to ensuring the relevance of the Platform and fostering Big Data actionability. CIAT conceptualized and developed the Big Data analytics capabilities that enabled the project, but also worked closely with growers' associations and other key stakeholders to gain access to and analyze relevant historical datasets, in order to ensure future actionability.

Key Enablers and Challenges



Enabling

Building capacity as a stepping stone for resilience

The scripts used for data analysis and climate forecasting are accompanied by tutorials and short training courses aimed at capacity building and empowerment of users at farmers' organizations.

Challenging

Measuring the impact of Big Data over time

The role of Big Data in resilience building is a relatively new domain in the international development field, particularly in the agricultural sector. The impact of Big Data can take many years to manifest and takes place at multiple scales, posing unique challenges to the design of monitoring and evaluation systems.

Challenging

The achievement of FAIR data

There is a growing consensus that research data should be findable, accessible, interoperable, and reusable (FAIR). Yet, the incentives of multiple actors including donors, private sector, researchers, and data subjects themselves may not always easily align. Different ethical, fiduciary, or personal interests may serve as disincentives to making data available.

Enabling

Empowering farmers' organizations and public institutions

Enhancing the capacity of institutions that act as bridges between farmers and scientists is key to building resilience. Co-design and co-development are central to these processes, as well as understanding farmer and institutional needs and challenges in the face of climate variability and change.

Enabling

Building on existing institutional strengths

Building on the broad applied research experience and the partnerships established by the CGIAR network was crucial in the design and launch of the Platform. Scientific credibility and collaborative work with country-level decision-makers and growers' associations were key to ensure buy-in from a broad set of stakeholders.

Challenging

Evolving data ethics and legal frameworks

The ability to capture and recombine digital data, including "live" data in real time, can impact human subjects in a variety of new ways that need to be better understood. Existing legal frameworks and ethics guidelines may not be evolving as quickly as multifaceted data-driven capabilities, which may have implications for technology, confidentiality, intellectual property, consent, access and sharing of benefits.

Recommendations

Building user capacity as part of Big Data initiatives serves a dual purpose: it ensures that Big Data is actionable and contributes to empowerment, both of which are key to resilience building. Initiatives in this field should strive to strengthen user capacities to use ICT tools, including state-of-the-art ICTs, modelling tools and data mining approaches.

Big Data thinking involves replicability thinking. Early success in Colombia has already allowed expanding activities into Honduras, and to the identification of site-specific yield-limiting factors in Mexico, Nicaragua, Argentina, Peru, Uruguay, Honduras and Ethiopia. Demonstrating impact is key for scaling out to other regions and countries.

The role of Big Data in resilience building is most effective when conducted from the bottom up. Farmer organizations, public institutions, and farmers themselves played a key role in designing the Platform, helping identify key sector-specific priorities. Improving data sharing and interoperability across different (public, private, non-profit, national, global) actors remains a priority, as well as developing agile, function-driven, iterative approaches to sharing and use.

Big data tools can become enablers of change across scales. This includes making smarter climatic decisions at the institutional and farmer level, including: the best variety to grow according to climatic conditions, the best planting period according to the climate in the next season, and the right amount of pesticides and fertilizers in specific geographical regions, among others. These decisions are key to better cope with, adapt and potentially transform in face of climate change impacts.

As the use of Big Data for resilience evolves, clear guidelines need to be developed for ethics and accountability. This process should involve data providers and users to define and promote the practices that best address the challenges of responsible data sharing and include technical (e.g., use of tracking systems or encryption), privacy and ethical issues (e.g., confidentiality, intellectual property rights, privacy protection, access and benefit sharing related to traditional knowledge and genetic information), among other aspects.



Additional Information:

- CGIAR Platform for Big Data in Agriculture: <http://www.cgiar.org/about-us/our-programs/cgiar-platform-for-big-data-in-agriculture-2017-2022/>
- UNFCCC Lighthouse Activity Award: <https://vimeo.com/243142401>

This case was prepared by the author with contributions from Daniel Jimenez and Julian Ramirez-Villegas, Consultative Group on International Agricultural Research (CGIAR) Research Program on Climate Change, Agriculture and Food Security (CCAFS) /International Center for Tropical Agriculture (CIAT).



VAMPIRE

An integrated perspective
to inform resilience
decision making

An initiative of Pulse Lab Jakarta

Rainfall anomalies such as droughts and flooding have a direct and tangible impact on the lives of millions of crop-growing families. Despite the economic growth achieved in recent years in countries such as Indonesia, rural districts are often prone to food insecurity.

The effects of climate-related hazards and variability on agriculture translate into delays in the harvest season (e.g., rice planting), lower production levels, and challenges in food access and malnutrition. Unfavourable coping strategies resulting from reduced yields (such as selling assets or taking up loans) further undermine the ability of low-income households to cope with and adapt to future shocks. In this context, making informed decisions is an increasing priority for resilience building.

From socioeconomic variables to food insecurity and climate change impacts, there are multiple factors that contribute to the vulnerability of agricultural producers and other everyday citizens. Being able to access timely and relevant information plays a key role in the ability of stakeholders to predict, cope with and adapt to the effects of shocks and stressors.

Despite the availability of multiple datasets containing information related to climate-induced

disasters, a number of these sources typically provide a fragmented view of the different dimensions of vulnerability in drought- and flood-prone areas.

The Vulnerability Analysis Monitoring Platform for the Impact of Regional Events (VAMPIRE) was developed in response to the 2015 El Niño, in collaboration with the World Food Programme (WFP) and the Food & Agriculture Organisation (FAO) in Indonesia.

VAMPIRE provides an integrated, multi-layered perspective of data that is critical to inform resilience-building decisions. It provides map-based visualizations of the extent of drought and flood-affected areas, as well as of the impacts that these have on food prices and the coping strategies undertaken by affected populations.

Resilience Snapshot

VAMPIRE & CORE RESILIENCE QUESTIONS

RESILIENCE WHERE?

Indonesia and Sri Lanka

RESILIENCE OF WHAT?

Communities adversely affected by climate-inducing disasters

RESILIENCE OF WHAT?

Climate-induced disasters, including drought and flooding

RESILIENCE FOR WHAT PURPOSE?

Strengthen livelihoods, food security and response strategies

RESILIENCE HOW?

It seeks to improve the ability of Indonesian and Sri Lankan citizens and decision-makers at the Ministry (central Government) level to make informed decisions based on integrated data on multiple vulnerability dimensions, to better prepare and cope with the impacts of climate-induced disasters.

Visualizing, Analyzing & Prioritizing for Resilience

VAMPIRE is a multi-tiered system that fuses several databases, allowing users to:

- Visualize the national socioeconomic survey and WFP's household food security surveys. This data provides information on the percentage and distribution of low-income, agriculture-dependent populations, as well as food insecure communities.
- Analyze data on rainfall anomalies and the Indonesian Vegetation Health Index. Rainfall anomaly is a measure of the amount of rainfall in a period compared to the long-term average for that time of year while the vegetation index is a proxy for drought.
 - Identify priority areas where people may require assistance based on the measure of economic vulnerability and exposure to drought.



Tech Buff Zone

VAMPIRE & THE V'S OF BIG DATA

BIG DATA VOLUME

TB

BIG DATA VELOCITY

Near-real time

BIG DATA VARIETY

- **Baseline Data Layer:** population data, socioeconomic data, food security surveys
- **Climate Layer:** rainfall anomaly, standardised precipitation index, vegetation health index
- **Impact Layer:** economic vulnerability, exposure to drought

BIG DATA VERACITY

The data collected is largely collected from verifiable government sources/databases.





How Does VAMPIRE Build Resilience?

Climate-related hazards evolve constantly over time, and along with them the ability of vulnerable populations to effectively cope with, adapt, and potentially transform. Making decisions that improve resilience to these hazards and that contribute to strengthen livelihoods, food security and response strategies requires understanding vulnerability from a broader, integrated perspective. VAMPIRE contributes to building resilience by:



Improving the capacity of government stakeholders to **prepare and respond** to shocks and stressors, reducing the time required to access and assess key information on rainfall and food security, and visualize it in high resolution and in near-real time. By combining baseline data on key vulnerability determinants (population, socioeconomic and food security), with climate data and impact analysis based on economic vulnerability and drought exposure, VAMPIRE contributes to more robust decision making.



Strengthening the **adaptive capacity** of agricultural sector stakeholders through a more in-depth understanding of the impacts of slow-onset climate phenomena, which can be used to better channel assistance to vulnerable populations.

The following are examples of the way in which VAMPIRE is contributing to build resilience through key resilience attributes, specifically in Indonesia and Sri Lanka where the system is already being implemented:



Resilience Buff Zone

VAMPIRE & RESILIENCE ATTRIBUTES



Robustness

It helps government stakeholders prioritize food security programs and tailor international assistance to areas in need.



Equity

By visualizing vulnerability in marginalized rural areas, it allows decision makers to prioritize actions and direct programs and assistance towards areas in need.



Redundancy

By providing multiple data layers from different sources, it gives a more complete view of drought impacts and improves planning and response strategies.



Diversity

It fuses multiple datasets with data on population, socioeconomic conditions, food security, rainfall anomaly, standardized precipitation index, vegetation health index, economic vulnerability and exposure to drought.



Scale

It integrates additional data sources and features. The Platform for Real-time Information and Situation Monitoring (PRISM), a disaster management information system, was recently developed and is being installed in the Ministry of Disaster Management of the Government of Sri Lanka



Rapidity

It shortens the time needed to access the key information needed to make decisions through an integrated, multi-tier platform.



Flexibility

By identifying new features and functionalities that could be added to the existing version of the platform, it provides decision makers with relevant data that responds to their evolving needs and priorities.

Key Lessons Learned: A multi-tier approach to resilience data

Data Access

Ensuring data accessibility is at the core of a functioning Big Data ecosystem. VAMPIRE fosters data access by providing a user-friendly interface where baseline, climate, and impact-related data can be visualized.



Data Assessment

Data integration can enable more robust assessment processes in complex settings. VAMPIRE combines and provides analytics of several layers of data in order to provide users with a broader perspective on the factors that can affect climate-induced hazards, including drought and flooding.



Data Application

Timing is crucial to ensuring the application of data into decision making. By enabling swift access to relevant information, VAMPIRE's data has been applied to decision-making processes related to drought, flooding, and food security by Sri Lanka's Ministry of Disaster Management and the Office of the President of the Republic of Indonesia.

Data Actionability

Ensuring better targeted resilience assistance and strategies is a key component of data actionability. Through its integrated approach to data, VAMPIRE is helping decision makers understand the evolution and impacts of slow-onset phenomena like El Niño in near-real time. This information is used to better target assistance from government and international organizations and ensure more impactful approaches to building the resilience of vulnerable populations. The system has been installed in the Office of the President of the Republic of Indonesia. Additional layers are being developed to improve flood monitoring and vulnerability models, which will be refined to accelerate disaster response.

Key Enablers and Challenges



Enabling

Responding to specific information needs

The design and development of the tool was attuned with decision-makers' needs in areas such as: identification of priority areas for programs, coordination of development assistance and disaster response.

Challenging

Visualizing complex data in user-friendly formats

Visualizing different kinds of complex data in easy-to-consume formats for government officials constitutes a challenge. At the same time, an inherent challenge exists with the current Standard Operating Procedures (SOPs), as there is no corresponding set of SOPs to compare it with.

Challenging

Constantly monitoring and ensuring privacy

While there are no direct privacy concerns with the platform, as only aggregated data (such as the socioeconomic survey results) and satellite images with a few kilometres' resolution are processed, data analytics approaches are regularly reviewed to ensure the highest level of privacy.

Enabling

Robust partners and datasets

While there are multiple sources of data on rainfall anomalies and food security, the platform utilizes widely recognized, robust datasets provided by WFP and FAO, which are broadly recognized sources and have established credibility.

Enabling

Dashboard features

A few convenient functions are included to help existing procedures, such as the ability to produce a report in PDF format and configure a shortcut (and save a configuration) for a specific country, specific layers, etc.

Challenging

Ensuring adoption

User adoption is key for sustainability. This involves the establishment of partnerships, the provision of training and continuous support, as the platform evolves. Collaboration with an entity that is versed in government procedures/processes is also a priority (e.g., WFP in this case).

Recommendations

Privacy is key for unlocking the potential of Big Data for resilience. The role of platforms such as VAMPIRE is closely linked to the ability of practitioners and decision-makers to develop a safe ecosystem with privacy principles that can guide and inform the design and implementation of Big Data initiatives for humanitarian and development purposes. Global Pulse developed a set of privacy principles for applications of Big Data and collaborates with the Privacy Advisory Group to further work in this field.

Collaboration is also crucial in the development of Big Data tools, particularly in the resilience field. VAMPIRE is the result of a collaboration between practitioners in the field of food security, food assistance and climate-induced disaster management, with data experts working to harness Big Data for development and humanitarian action. This collaborative process contributed to shaping the focus and ensuring the relevance of the tool.

Big Data solutions need to be constantly improved to ensure their relevance and applicability in line with the users' needs. The experience of VAMPIRE gave rise to PRISM, a tool that refined VAMPIRE's data acquisition mechanism and shortened the time between updates across most data sets. Responding to emerging information needs, coupled with challenges of decision makers, PRISM includes the Standardised Precipitation Index drought indicator and automates vegetation health indices processing and analysis. These features are in turn being used to update and strengthen VAMPIRE.



Additional Information:

- <http://pulselabjakarta.id/vampire/>
- <https://medium.com/pulse-lab-jakarta/tracking-the-sdgs-using-big-data-dad0ad351f2e>
- <https://medium.com/pulse-lab-jakarta/scaling-up-our-drought-impact-tracker-57674b84cc83>
- <https://www.unglobalpulse.org/news/new-vulnerability-monitoring-platform-assist-drought-affected-populations-indonesia>
- <https://medium.com/pulse-lab-jakarta/fusing-datasets-to-track-the-impact-of-disasters-in-indonesia-and-beyond-vampire-is-on-it-ed13fe8e6ff6>

This case was prepared by the author with contributions from Dwayne Carruthers and Jonggun Lee, United Nations Global Pulse – Pulse Lab Jakarta.



Conclusions

Emerging experiences with the use of Big Data suggest that the speed and scale at which information and knowledge are produced and shared can influence the responses to global sustainability challenges. They also suggest a rising need to better articulate information, knowledge and learning among stakeholders and across scales (e.g., local, regional, national and global) to respond more effectively to the impacts of natural disasters and climate change, among other shocks and stressors.

Development programs, research and policy strategies need to go hand in hand with the Big Data revolution to ensure that we understand, learn from and benefit from the rapid growth of global interconnectedness, and most importantly, that it translates into more robust and sustainable development pathways for vulnerable populations.

The cases presented in this document demonstrate the importance of bridging the technological realm of the Big Data revolution with the practical implications of its use, in order to strengthen the ability of vulnerable systems to better cope with, adapt and potentially transform in the face of shocks and stressors.

One of the main challenges for Big Data actionability is determining how to use large volumes of data for describing, predicting,

diagnosing, or engaging in action. This involves learning how to make sense of the data and applying that to context-specific actions.

In data-poor contexts, hybrid approaches to Big Data may be required. This refers to finding a balance between traditional data collection processes, and emerging digital means such as satellite imagery and social media. Integrating human and digital components can provide a more complete understanding of local contexts, foster the inclusion of diverse actors in the data cycle, and help address existing information gaps.

A crucial part of this process is gaining a better understanding of

the limitations of Big Data to build ecosystems' resilience, and the resilience of at-risk communities where poverty prevails, and where technology access remains scarce. Developing a project-specific data strategy could help to identify and address the risks and shortcomings of Big Data. Such a strategy could include developing a roadmap to ensure that Big Data complements other data sources, to engage diverse stakeholders throughout the data cycle, to address security and ethical concerns, and to enable data's role in decision making, among others.

Developing a research and learning agenda on Big Data and resilience also constitutes an important step to inform, complement and strengthen future work in this field.

An Emerging Research Agenda: BD4R

The following topics emerged from the analysis of the cases presented in this document, and can be used to inform the design of new research and practice at the intersection of Big Data and resilience:

CROSS-SCALE AND COMPLEX DYNAMICS:

Further research at the intersection of Big Data and resilience can provide new insights about the challenges and opportunities of measuring resilience across scales and spatial levels. This includes using large data sets to better understand, track and learn from complex systems dynamics, its relevance and implications for resilience programming.

RESILIENCE MONITORING AND EVALUATION (M&E):

The use of Big Data as part of resilience M&E remains largely unexplored. Future research and practice could explore how resilience measurement approaches can integrate and apply new data sources, methods and technologies, and how practitioners can leverage the potential of Big Data to strengthen resilience programming and learning.

BUSINESS CASE FOR RESILIENCE:

Practitioners need to be able to convey evidence of impact to a variety of stakeholders to achieve increased and sustained investments. Further research and practice can provide new knowledge and guidance on how to leverage Big Data to strengthen in resilience measurement approaches and communicate evidence.

POWER, EQUITY, GENDER AND MARGINALIZATION:

By exploring both the potential as well as the risks of Big Data, research can help address potential detrimental impacts related to social, power and gender. This includes the role of open source data tools in resilience measurement, transparent data infrastructure, the development of local skills and data ownership, as well as ethical principles for data sharing, among other factors.¹⁶

INNOVATION AND RESILIENCE:

Research can help identify novel tools and approaches to Big Data usage, as well as practical examples on the use of emerging technologies as part of resilience programming.

PRACTITIONER-ORIENTED GUIDELINES:

Future work in this field should address the growing demand for guidance on how to leverage data to the benefit of NGOs and international organizations implementing resilience programming in complex development settings. This includes developing guidance and best practices on operational data collection and use, particularly in the event of disasters or shocks, ethical concerns and data protection mechanisms. It also involves mechanisms to ensure that data is used to inform action in both short- and long-term events, in crisis settings, when life-saving, time-sensitive decisions must be made with imperfect or scarce data, and also to inform chronic and long-term responses to stressors.



Regardless of the context of implementation, the shocks or stressors addressed, or the resilience approach adopted, the experiences presented in the Storybook indicate that, going forward, the focus should be on both the information and on the effective use of that information, not on the tools.

The local relevance and appropriateness of the content is key for Big Data's role in building and supporting resilience. Understanding the wider data ecosystem, including the enablers and constraints for data to be effectively accessed, assessment, applied and used, will be key for ensuring that data leads to change.

Endnotes

- ¹ *The Economist* (2017). Fuel of the future: Data is giving rise to a new economy. Retrieved from <http://www.economist.com/news/briefing/21721634-how-it-shaping-up-data-giving-rise-new-economy>
- ² Crawford, K., Faleiros, G., Luers, A., Meier, P, Perlich, C., & Thorp, J. (2013). *Big data, communities and ethical resilience: A framework for action* (White paper). Bellagio/PopTech Fellows. Retrieved from https://s3.amazonaws.com/poptech_uploaded_files/uploaded_files/66/original/BellagioFramework.pdf
- ³ Laney, D. (2001). *3D data management: Controlling data volume, velocity, and variety*. META Group. Retrieved from <http://blogs.gartner.com/doug-laney/files/2012/01/ad949-3D-Data-Management-Controlling-Data-Volume-Velocity-and-Variety.pdf>
- ⁴ Data-Pop Alliance. (2015). *Big data for resilience: Realising the benefits for developing countries*, (Synthesis report), p. iii.
- ⁵ Letouzé, E. (2012). *Big data for development: Challenges and opportunities*. UN Global Pulse. Retrieved from <http://www.unglobalpulse.org/sites/default/files/BigDataforDevelopment-UNGlobalPulseJune2012.pdf>; Letouzé, E. (2014). Big data for development: Facts and figures. *SciDev*, Retrieved from www.scidev.net/global/data/feature/big-data-for-development-facts-and-figures.html; Pham, T., Apparicio P., Gomez, C., Weber, C., & Mathon, D. (2014). Towards a rapid automatic detection of building damage using remote sensing for disaster management: The 2010 Haiti earthquake. *Disaster Prevention and Management* 23(1) pp. 53–66; Sood, M. (2014). *Enhancing resilience: Big data analytics & data science*. Retrieved from http://cmimarseille.org/sites/default/files/newsite/library/files/en/Session%205_Sood_Manish_May%2023_%202014_0.pdf; UN Global Pulse (2016a) *Haze gazer: A crisis analysis tool*. Retrieved from <https://www.unglobalpulse.org/projects/haze-gazer-a-crisis-analysis-tool>; UN Global Pulse (2016b). *Integrating big data into the monitoring and evaluation of development programmes*. Retrieved from http://unglobalpulse.org/sites/default/files/IntegratingBigData_intoMEDP_web_UNGP.pdf
- ⁶ Ali, A., Qadir, J., ur Rasool, R., Sathiaseelan, A., Zwitter, A., & Crowcroft, J. (2016). Big data for development: applications and techniques. Big Data Analytics 2016, 1:2, DOI 10.1186/s41044-016-0002-4; Whipkey, K., & Verity, A., (2015) *Guidance for incorporating big data into humanitarian operations*. Digital Humanitarian Network. Retrieved from http://digitalhumanitarians.com/sites/default/files/resource-field_media/IncorporatingBigDataintoHumanitarianOps-2015.pdf
- ⁷ UN Global Pulse. (2017). *Harnessing big data for development and humanitarian action*. Retrieved from <http://www.unglobalpulse.org/projects>
- ⁸ Ospina, A.V. (2016). *The dynamic resilience wheel (DREW)*. Baltimore: Lutheran Work Relief (LWR).
- ⁹ IBM. (n.d.). *The four V's of big data*. IBM Big Data and Analytics Hub. Retrieved from <http://www.ibmbigdatahub.com/infographic/four-vs-big-data>

¹⁰ Heeks, R., Ospina A.V. (2018) Conceptualising the link between information systems and resilience: A developing country field study. *Info Systems J.* 2018;1–27. <https://doi.org/10.1111/isj.12177>; Ospina, A.V. (2013) *Climate Change Adaptation and Developing Country Livelihoods: The Role of Information and Communication Technologies*, PhD thesis, IDPM, University of Manchester, UK.

¹¹ Heeks, R. (2005a). *Foundations of ICTs in development: The information chain* (eDevelopment Briefing No. 3). University of Manchester: Development Informatics Group. Retrieved from http://hummedia.manchester.ac.uk/institutes/gdi/publications/workingpapers/di/dig_briefing/DIGBriefing3Chain.pdf

¹² Heeks, R. (2005b). *Foundations of ICTs in development: The Onion-Ring Model* (eDevelopment Briefing No. 4). University of Manchester: Development Informatics Group. Retrieved from http://hummedia.manchester.ac.uk/institutes/gdi/publications/workingpapers/di/dig_briefing/DIGBriefing4Onion.pdf

¹³ Schindler, D. W., Carpenter, S. R., Chapra, S. C., Hecky, R. E., & Orihel, D. M. (2016). Reducing phosphorus to curb lake eutrophication is a success. *Environmental Science and Technology*, 50(17), 8923–8929. <http://doi.org/10.1021/acs.est.6b02204>

¹⁴ Higgins, S. N., Paterson, M. J., Hecky, R. E., Schindler, D. W., Venkiteswaran, J. J., & Findlay, D. L. (2017). Biological nitrogen fixation prevents the response of a eutrophic lake to reduced loading of nitrogen: Evidence from a 46-year whole-lake experiment. *Ecosystems*, 1–13. <http://doi.org/10.1007/s10021-017-0204-2>

¹⁵ Chamorro, A., Minnemeyer, S., & Sargent, S. (2017, February 16). *Exploring Indonesia's long and complicated history of forest fires*. World Resources Institute. Retrieved from <http://www.wri.org/blog/2017/02/exploring-indonesias-long-and-complicated-history-forest-fires>

¹⁶ Poptech & RF Bellagio Fellows. (2013). *Seven principles for big data and resilience projects*. Retrieved from <http://www.100resilientcities.org/seven-principles-for-big-data-and-resilience-projects/>

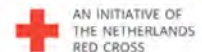
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