Data to Decisions

Valuing the Societal Benefit of Geospatial Information

A Workshop organized by the

GEOValue Community in Collaboration with OECD, NASA, and USGS

March 10–11, 2016

Proceedings

In Memory of

Molly Macauley

"What we're talking about is profound. Earth observing is like looking in the mirror."

March 11, 2016

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Introduction

These proceedings include extended abstracts provided for the Data to Decision Workshop. The workshop brought together scholars and stakeholders to identify best practices for developing and implementing frameworks to capture the societal value of geospatial information for both public and private uses. The two-day workshop focused on monitoring, mitigation, response, and resilience related to natural disasters—weather events including earthquake, tsunami, drought, flooding, and volatile weather; climate; and environmental concerns, such as water and ecosystem-based management that recognizes and honors the land–water–energy nexus. The organizers sought to provide opportunities for participants to demonstrate and compare approaches to valuation of geospatial information and forge a path forward for research that leads to standards of practice. The objective was to create a framework to identify and implement best practices for capturing the societal value of geospatial information for both public and private uses. To facilitate this effort, participants contributed case studies, use cases, and information from research that trace the information flow end-to-end from earth observation and data acquisition systems to decisions by end users.

Disaster risk reduction and ecosystems management support the UN Sustainable Development Goals, are in the nine GEO Societal Benefit areas, and are included in the U.S. National Plan for Civil Earth Observations, and both the NASA Applied sciences and USGS Science strategy. Observation systems are one or more sensing elements that collect observations of the Earth, measure environmental parameters, or survey biological or other earth resources. Observations from satellite systems, as well as airborne, terrestrial, and marine networks that intersect with the human dimension support better public and private decision-making.

In preparing their discussions for the workshop, participants were asked to consider how the work they presented could inform decisions and decision-making processes. How does the work address societal issues at a local or national level? What stakeholders and other constituencies are involved or affected?

The goals of the workshop included:

- Demonstrating and comparing approaches to valuation of geospatial information,
- Identifying one or more case studies to further review as examples for a range of subsequent applications, and
- Forging a path forward for research that leads to standards of practice.

Societal benefit focus areas included:

- Disaster mitigation, response, and resilience
- Natural disasters, extreme events that include earthquake, tsunami, wildfire, drought, flooding and extreme weather
- Ecosystems (terrestrial, freshwater, and ocean) ecosystem based Management that recognizes and honors the land-water-energy nexus.

Acknowledgements

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- The Organization for Economic Co-operation and Development (OECD)
- National Aeronautics and Space Administration (NASA)
- United States Geological Survey (USGS)
- The Group on Earth Observation (GEO)
- Euro SDR
- East Carolina University (ECU), North Carolina, U.S.

The organizers would like to thank NASA and USGS for their support of this workshop under NASA grant NNX15AT69G, and USGS grant G16AC00058 to East Carolina University, NASA grant NNX14AO01G to J&F Enterprise and USGS grant G14AC00303 to the University of Colorado. We would also like to thank GEO and Euro SDR for contributing financial support to participants and OECD for providing the workshop venue and logistics support.

Any opinions, findings, and conclusions or recommendations expressed in this material are those of the contributors and do not necessarily reflect the views of NASA, USGS, GEO, Euro SDR, or ECU.

The workshop included 77 participants coming from Europe, America, Africa, and Asia, representing international organizations, public and private sectors, non-government organizations, and academia. A list of participants and organizers is provided in Appendix 1. Summaries of workshop discussions are available in the Final Report of the workshop available on request.

Keynotes (Summaries)

Dr. Suzette Kimball, Director of the U.S. Geological Survey (USGS), *"Societal Benefit of Geospatial Information: Scientific Basis and Research Needs."*

Dr. Kimball stressed the importance of openly sharing geospatial information and linking science to decisions. She referenced the prior socioeconomic workshop held in 2014 on the socioeconomic impact and value of open geospatial information, highlighting the importance of accessibility and participation in enhancing societal benefits, and the need for case studies to improve understanding and uses of geospatial data and methods for estimating benefits. She briefly discusses the USGS charge regarding a Science and Decision center and the value of natural resources. USGS is responsible for providing non-advocacy scientific data that is important to policy makers. Science-driven geospatial data can help stakeholders make effective decisions about critical issues including ecosystem loss, climate change, and limits on resources and water. Addressing these challenges involves difficult choices for which people need timely, well-integrated information.

USGS focuses on predictive capabilities, on systems rather than disciplines, on looking beyond the geological to human impact. We need to develop better understanding of the uses of information, benefits of information, importance of open access to information, and assessment of impacts.

The Science and Decision center will provide focus by applying economics to evaluate social impacts, tradeoffs, and other related concerns. Researchers and stakeholders need to understand societal impacts and the best practices for collecting and assessing data. Results of the workshop will be important to governments and to taxpayers worldwide. Open sharing of geo-spatial and earth observation data that can inform decisions at all levels are particularly critical for decision making, particularly for communities and countries that don't have the capacity to collect and apply data to problems. In concert with other agencies, a USGS goal is to make information readily available.

Kimball identified critical challenges:

- Can we develop and apply methods that are methodologically appropriate and result in timely results?
- Can the community develop key standards that are common to societal benefit studies?
- Can we identify and develop policies that will advance efforts to enhance the use and value of scientific geospatial information including the understanding and measurement of societal benefits?
- Can we develop partnerships that span disciplines, the public, private, and academic sectors, and political boundaries?
- How can the science of using geospatial information best complement the science of obtaining new geospatial information?

Outcomes

President Obama noted the importance of broader citizen participation in science and planned to enhance and build innovative approaches that involve citizens and communities. Such initiatives will increase the public's appreciation of science and help professionals understand community needs. NOAA, NASA and other agencies are coming together to develop strategies to meet these needs.

A key issue is balancing conflicting needs for timely and rigorous information. Another is the need to reduce uncertainty. The previous Washington workshop stressed the need for case-studies and proof-of-concept work. Case studies enable U.S. to explore interrelationships and tradeoffs. A focus on disaster and risk reduction is important because the issues are not specific to any nation.

Robert Mendelsohn, Yale, USA, *"Using Earth Observation in Economic Analysis"*

Dr. Mendelsohn's keynote focused on direct uses of earth observations by economists. Environmental management critically relies on "big" geospatial data. However, "Big Data" is not valuable unless it is carefully processed and analyzed. Economists depend on high frequency geospatial weather and climate data across space and time. High quality data describing extreme events informs development of strategies to protect people and economic activity. Dr. Mendelsohn gave a number of examples illustrating the use of geospatial data. One example on climate change, contrasted immediate versus long term trends, across space.

Geospatial data could be made more useful: many earth observations are not directly interpretable, requiring translation by remote sensing experts. Remote sensed observations need geo-referencing into cells, while economic data and decisions are organized by political units such as counties, states, and countries.

- Urban v. Rural—Cities are a focal point during extreme events because more people are affected. A research challenge is to identify the urban structures that support higher density without increasing risk. If, however, we measure damage/capita, that measure is much lower in cities than in rural areas leading to a conclusion that urbanizing populations makes people safer.
- Energy data is useful for measuring cause and effect between energy and pollution. Geospatial measurements of pollution concentrations have helped determine the consequence of different methods of energy production. The key to making an integrated assessment is capturing the information and creating models that link to consequences and back to specific emissions so that it is possible to target most harmful emissions.

Land use planning will become ever more important because people are competing for ever scarcer remaining land resources. In the future, better land use plans must be developed, such as restricting the expansion of cities, which is socially desirable. We need data for making these types of decisions.

Could geo-spatial data be more useful? Geospatial data are valuable but need to be analyzed to be useful.

- Many earth observations are not directly interpretable

- Economic data and decisions are organized by political units which do not conform to earth observation units of analysis
- Gov't agencies depend on private firms to process public data for public use. The privatization of processing can reduce public access and sidetrack an open data policy.
- The societal gain of an open data policy for providing valuable geospatial data however, if data are not analyzed and put in a usable form, data are not being used.

Jeffrey K. Lazo, National Center for Atmospheric Research, *"The Socioeconomic benefits of Hydro-Meteorological information"*

Dr. Lazo, presented the Weather Information Value Chain referring to several studies and commenting on the quality and availability of information used for "value chain" studies. He identified a fundamental need for studies to be policy-relevant, cost-appropriate, and high quality.

Dr. Lazo gave the example of an empirical study of the relationship between economic output and weather variability**.** All sectors and all states show significant economic sensitivity to weather variability. The U.S. GDP varies by up to $485 billion a year (2008)—about 3.4%—due to weather variability. When he discusses the value chain, the chain includes not just the "geo-spatial" information but the entire communication/decision-making value process—noting in particular that increasing accuracy of geo-spatial information does not translate necessarily into increased value. Why use economics? The focus of the study on economics allows for program evaluation and justification, determining the value relative to user goals, and prioritization or reallocation of resources. The study should highlight the methods and rigor. The need for high quality studies is related to need for studies that do a better job of tracing the information flow end-to-end from the geospatial data acquisition system to decisions by end users. The value of weather may include the economic impact of weather, the value of current weather information, the value of improved weather forecasts, the value of research to improve forecasts, and the value of improving dissemination, decisions, etc. For example, the value of current weather information is estimated at $236 (U.S.) per household per year, with a benefits-cost ration of 6.2 to 1. Dr. Lazo referenced a book on *Valuing Weather and Climate: Economic Assessment of Meteorological and Hydrological Services* by the World Meteorological Organization, World Bank Group, Global Facility for Disaster Reduction and Recovery, and United States Agency for International Development, WMO No. 1153, Geneva, Switzerland. These organizations have a strong interest in improving the quality, transparency, and usefulness of Socioeconomic Benefits studies.

Dr. Lazo described the weather information value chain as including observations, modeling, forecasting, dissemination, communication, interpretation, decisions, and outcomes. The decisions can be analyzed ex-ante, and the outcomes ex-post. It is the *potential to make different* decisions using geo-spatial information given the decision-maker's decision context (objectives, resources, and constraints) that generates economic value. There are a number of primary valuation methods such as non-market valuation, economic decision modeling, and avoided cost/damage assessment.

To answer the workshop objectives, Dr. Lazo described three use case examples respectively focused on end user value model, non-market valuation (extreme weather event) and an ex-post case study (wind shear warning). He recommends that all major investments or changes in hydro-met services should undertake economics analysis.

Recommendations

- All major investments in geospatial information infrastructure should require economic analysis.
- Evaluate contribution of behavioral economics to decision models
  Need primary valuation critical review and consolidation

Barbara Ryan, Executive Director of GEO Secretariat, *"Data to Decisions: Closing the Gap with the Group on Earth Observations (GEO)"*

The GEO vision is to realize a future wherein decisions and actions, for the benefit of humankind, are informed by coordinated, comprehensive and sustained Earth observations and information. GEOSS is clearly at the start of the Earth Observation supply chain. The challenge is to integrate all of the information.

There are still some gaps in GEO membership, which includes 102 member states and 92 participating organizations. The organizations highlighted either have a representative in the room or are related to disasters or biodiversity.

Over the last year, new Societal Benefit Areas (SBAs) were restructured around actions required. The resulting work program initiatives are related with the case studies topics presented yesterday (ecosystem services, and disaster risk reduction). Ms. Ryan presented the list of GEO foundational tasks and highlighted Community Development task CD-03, which assesses the benefits from Earth Observations and of their socio-economic value.

There are several kinds of Earth Observations, such as land temperature, sea surface temperature, and vegetation for example. Earth observations and geospatial data can be combined, where for example, land temperature, total rainfall, and vegetation are environmental factors associated with Malaria transmission. The results are reflected in the Sustainable Development Goals (SDGs), The 2030 Plan for Global Action—Article 76: "We will promote transparent and accountable scaling-up of appropriate public-private cooperation to exploit the contribution to be made by a wide range of data, including Earth observation and geo-spatial information, while ensuring national ownership in supporting and tracking progress." UN conventions, such as the one on biodiversity help closing the loop by inviting "Parties, indigenous and local communities and other relevant stakeholders to collaborate with the Group on Earth Observations Biodiversity Observation Network and other relevant organizations that contribute to building observing systems and to biodiversity monitoring". Nations need support and encouragement to continue making investments. At the 2015 Sendai UN conference on disaster risk reduction, there was work on an international framework on EO. The Sendai Framework included language recognizing that Earth observations have a clear role in

Disaster Risk Reduction. GEO and other partners proposed to establish a Synergy Framework for the Integration of Earth Observation Technologies into Disaster Risk Reduction.

Ms. Ryan emphasized a couple of points: open sharing of data, and what is being done with the downloaded data, with focus on annual economic benefits. For example, the University of Maryland has performed an analysis of forest data. Australia has developed a data cube (with every pixel rectified) and has performed flood risk analysis at pixel level. Open data is a precursor to bringing users to the table. The activities below were highlighted. The G20 agricultural ministers have engaged, leading to the GEOGLAM system, a crop information system for decision- making (The crops currently include maize, rice, wheat, soybeans). Another example has to do with visualizing the impact of public policy. Corn and soybeans used to be planted in rotations until the ethanol legislation resulted in corn being planted only. Barbara concluded by mentioning that "Countries have borders, Earth Observations do not".

Mark Pelling, King's College London, *"Risk Information to Action: integrating risk information into social research for policy impact"*

Mark Pelling is a human geographer who focuses on sustainable development from the perspective of failures and looking at increases in inequality. Mr. Pelling is on the steering committee of King's College Center for Integrated Research on Risk and Resilience (CIRRR) where he heads one of working groups (risk information to action), and he works with the Belmont Forum.

Mr. Pelling has shifted from describing problems to opening solution spaces. Social science history reveals work at the grass root level and at very high levels; Mr. Pelling is looking at the possibility of operating in the middle space where GEO Data may be most important. This positioning raises two questions: Can GEO Data play a role in that framework? What is the empirical question to be solved, and what about governance?

Three projects Mr. Pelling described use GEO data for decision-making.

Story One: Urban risk management in Africa. This is a three-year project, in which seven countries are collaborating. The projects faced problems including data scarcity (data is either not accessible or not affordable); fragmented land-use, which geospatial data may be able to help resolve; and polycentric planning regime involving many social actors. Can we bring GEO Data to enable discussions, recognizing for example, the importance of boundaries? GEO Data brings legitimacy to the project because it is seen as neutral, and involves a level of technical expertise suitable to open up the conversation. The solution space includes a database of sources available via online portal (for legitimacy), a focus on city infrastructure analysis with particular attention to boundaries, recognition of the importance of ground truth, and attention to hazard history and interactions.

Story Two: Metropole, urban resilience in UK, U.S., and Brazil. The problem space in this project includes data variability and an increasing gap between historic and contemporary local sea-defense planning rights and powers. A challenge is not lack of risk awareness but the need to re-think how to approach risk management and data scarcity.

Strategic conversations were held within local governments—with local, regional and national stakeholders, and between local, regional and national stakeholders. Again, geospatial data projects are considered a safe science partner—political neutrality, technical—Bespoke sea-level rise hazard assessment and adaptation cost-benefit analysis. Geospatial data is handed over to institutional analysis to explore solutions, such as the development of an Adaptive Capacity Index.

Mark gave the example of an Integrated Framework to analyze local decision- making and adaptive capacity to large-scale environmental change. He looked at a flood hazard risk model based on LiDAR risk data; the data was very difficult to use.

The adaptive capacity index is designed to improve understanding of the barriers to adaptation planning:

- How values, demographics and cultural factors influence stakeholder receptivity to locally specific scientific and economic data and governance approaches
- What decision-making tradeoffs exist around costs, risk and public good for possible adaptation options, and local willingness to support action
- Regional adaptive capacity—institutional factors that support the ability of risk management actors to adapt and mobilize change.

Story Three: Transformation and resilience on urban coasts. This case focused on meeting the needs of mid-century flood risk and heat wave scenarios. Data accessibility across cities is a problem. Problems include susceptibility, lack of coping capacity, and lack of adaptive capacity. Detailed policy analysis was undertaken; it took a year and a half to get modeling data out.

The three examples illustrate a combination of geospatial data modeling and social analysis and highlight the need for improved dissemination of data (including access and awareness). Sources available to organizations and community groups are essential to improve local decision making processes. Trust building and engagement through transparency and co-production is also important. The local recognition of potential impacts of disaster risk, including those associated with climate change, facilitates galvanizing local action with implications for wider urban governance.

Extended Abstracts (in alphabetical order by first author)

Arnold, Lesley. *Spatial Data Supply Chain and End User Frameworks: Towards an Ontology for Value Creation*

Bamutaze, Yazidhi. *Evaluation of geospatial data utilization for disaster governance in Uganda*

Berenter, Jared; Morrison, Isaac. *The Effect of "Pace of Onset" and "Administrative Scale of Environmental Hazards" on the End-User Value of Satellite Data for Environmental Decision-Making: A Contextual Analysis Based on Fieldwork in Central America, Africa, and the Himalayas*

de Bruin, Styze; Bregt, Arnold; Herold, Martin; Roman Cuesta, Rosa Maria; Tsendbazar, Nandin-Erdene. *Fitness-for-use of geospatial information products: uncertainty and value*

Campbell, Gordon. *ESA use of satellite derived information for ecosystem service assessment*

Lovison-Golob, Lucia. *Data to Decisions: Valuing the Societal Benefit of Geospatial information in case of Disasters such as Earthquakes and Tsunamis*

Miller, Benjamin. *The Not-so Marginal Value of Weather Warning Systems*

Murambadoro, Miriam; Mambo, Julia. *Enhancing the uptake of climate change information through participatory approaches for learning in South Africa*

Papenfus, Michael. *Using ocean color satellite data to estimate economics benefits associated with monitoring and preventing harmful algal blooms*

Sylak-Glassman, Emily; Lev, Steven; Gallo, Jason. *A method to estimate societal benefit derived from Earth observations: An example from the United States' National Earth Observation Assessment*

Woolridge, Charles; Kutny, Mary Ann. *Understanding and Assessing the Value of Improved Satellite Data for the Users of Operational Sea Ice Products and Information*

Yetman, Gregory; Squires, John; Chen, Robert S.; Downs, Robert R. *Spatial Information for Disaster Planning and the Reinsurance Industry*

Zhu, Zhiliang. *Assessing carbon sequestration potential as an ecosystem service for publicly managed lands in the United States*

Spatial Data Supply Chain and End User Frameworks: Towards an Ontology for Value Creation

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ABSTRACT: Organisations that collect, manage and distribute spatial information currently do so without necessarily understanding the purpose for which the information will be used and the consequential value to end-users. Conversely, end- users (businesses and individuals) know what knowledge they require, but find it difficult to locate the information they need, when they need it and in a format that is of value to them. The point of issue for data producers is "Are we delivering the right value?" Consumers today want to query *at will* data to meet their immediate need. For this to happen, a new approach to spatial data supply chains is required. This paper proposes a *Pull Production Model* that is based on an end-user query driven process that delivers knowledge to users just when it is needed. All data producers need do, is make their data openly available. The data producer and end-user perspectives are encapsulated in a Supply Chain Framework and End-user Value Chain Framework (respectively) and will be used to develop an Ontology for value creation.

***Keywords*: Value, Supply Chains, Ontology, Query-driven.**

1. INTRODUCTION

Providing value to end-users of spatial data products will become a reality when industry is able to deliver knowledge in a way that allows end-users to achieve their goals. This requires a fundamental shift in thinking.

The value of spatial data to consumers is not the actual data itself, but rather the usefulness of the knowledge that is extracted from the data. This means the *value proposition* is not so much about *how* consumers use information; but rather *why* they are using it.

A team of researchers at Curtin University, including ten PhD candidates, is examining aspects of spatial data supply chains with a view to delivering value in the users' context [1]. The research collectively hypothesizes that the ultimate goal of end-users is knowledge, and that delivering this knowledge is what affords the most value – financially, socially and ethically.

Governments, businesses and individuals today want to make informed decisions, and know that their conclusions are based on the best available evidence. What they don't want, are the costly and time consuming overheads associated with finding, downloading, reworking and analysing data, and the anxiety of not knowing if the quality of the data is fit for their purpose.

A new approach is required; one that interfaces the data producer's *Push* production system with the end-users' requirement for a timely, customised pull-based knowledge service. A Goal-Directed Query Use Case for determining the *likelihood of flooding in an area* is used to conceptualise how the *Pull* production approach can deliver value in the user's context.

2. THE DECOUPLING POINT

Spatial data supply chains today push data to the end-user via spatial web portals. The value of this information typically relies on being able to anticipate end-user needs and their quality requirements to be successful. This approach is proving problematic given the unforeseeable and diverse nature of end-user goals.

In contrast, the *Pull* production approach is query driven, where users draw at will representations of knowledge. Pull systems have gained considerable traction in industries that provide digital content. The mass media has been transformed by enabling customers to pull at will; text, voice and video. The spatial industry however, needs to go one step further. It's not just the ability for the consumer to retrieve content that provides value, but rather the response to a query and the knowledge it provides.

The interface between the Push and Pull systems is the decoupling point. This is the point where demand push and demand pull meet. It is the point at which a product moves from being a generic (sub-assembly) product to a customised (made to order or query driven) product. The challenge is to balance supply costs and value to the consumer.

2.1. CONCEPTUAL MODEL

A conceptual *Pull Production* model is presented in Figure 1. The model leverages *Open Data* principles and identifies with on- the-fly spatial analytics. The premise of the model is that suppliers make their data accessible as web services and expose semantic attributes using Resource Description Framework (RDF) so that the meaning of data can be interpreted automatically. Once data is accessible, the end-user query can be enacted. Query processing is envisaged as six steps that constitute the Decoupling Point Automated Services (Fig. 1). Research is addressing each of these steps. They are:

1. *Interpret*: Natural language query decomposition to interpret knowledge required and thus data needs [2]
2. *Retrieve*: Semantic search and filtering techniques to find data [3,4]
3. *Process:* Orchestration of geo-processing web services using an ontology to link processes, such as calculate, buffer and overlay etc. [5]
4. *Portray:* Visualization of query results (map, image, chart, text, table etc.)
5. *Rank*: Assign a rank to results based on criteria (accuracy, completeness, timeliness, cost, etc.)
6. *Deliver*: List ranked results from which end-users may select

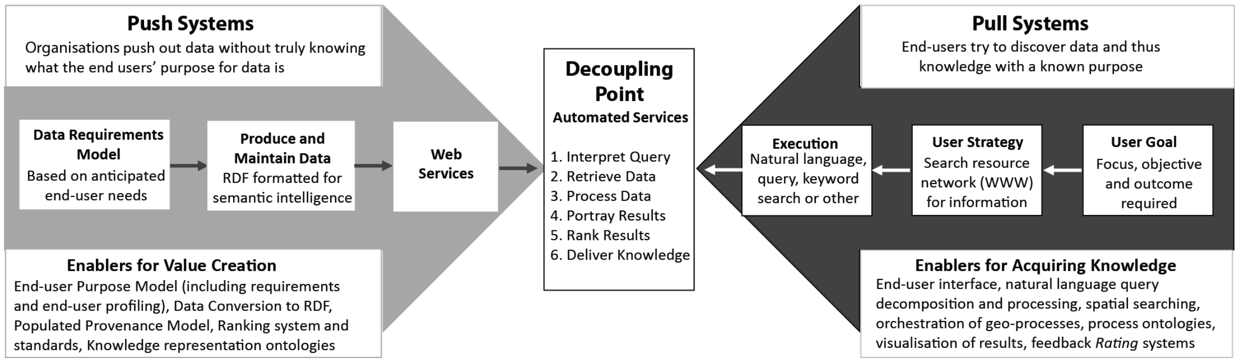

Fig 1. Conceptual model for next generation spatial data supply chains

To implement these steps, a root cause analysis into the underpinning issues of supply chains has given rise to several other challenges that require investigation. This includes research into enablers for acquiring knowledge, such as the automation of current predominantly manual geo-processes e.g. data conflation [6], federation and generalization, which form part of the orchestration process; and the creation of knowledge representation ontologies for specific domains of discourse (Fig. 1).

Research is also required into enablers for value creation. This includes the need to capture data provenance (metadata and lineage) [8] to understand data authoritativeness (or otherwise) to rank query results. There is also a need for an industry standard for calculating rankings and a mechanism, such as an info-graphic, to readily communicate these rankings to users (Fig 1.) Industry standards for ranking do not currently exist for spatial data, although they are prevalent in many other sectors, such as the hotel *star rating* system, television programming codes and nutrition panels on food packaging. The customary spatial metadata approach is often inadequate for the task or too complex for end-users to understand.

3. CASE STUDY

To demonstrate the conceptual model, a community disaster resilience scenario is used to explain the methods (Fig. 2). Research by Bing Tan *et al* [5] is using a flood case study to examine automatic process orchestration to answer the end-user query "What are the chances of flooding in my area?" The query encapsulates knowledge that can be decomposed using semantic web technologies and Natural Language Processing to understand what the query actually means. The Natural Language Processor draws out the key words, which in effect makes the query machine-readable [2]. When combined with a vocabulary, it is possible to infer meaning from the keywords (area infers location), and search for domain ontologies, such as a weather ontology (SWEET- Sematic Web for Earth and Environmental Technology) or Rainfall Prediction Ontology. Once located these domain ontologies provide links to relevant data sources and web services, such as a rainfall web processing services (WPS).

However, invoking WPS in the right order is posing a challenge. While the OGC® WPS standard specifies inputs, outputs and functions, it does not specify metadata to orchestrate processes. As a consequence, Bing Tan *et al* [5] are applying Artificial Intelligence to develop inference rules and process logic to chain web services in a way that satisfies a query. This work is in progress and will inform a revision of the OGC® open standard for WPS.

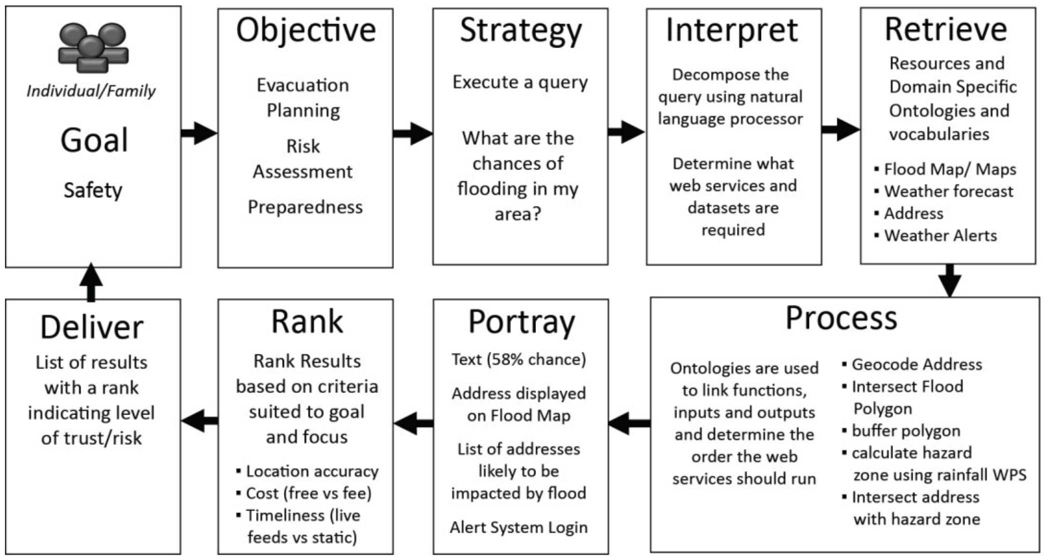

Fig 2. Goal-directed Query Use Case to determine the likelihood of flooding

3.1. TOWARDS AN ONTOLOGY FOR VALUE CREATION

While research continues to develop pull production methods, a conundrum for data producers remains. How to strike the right balance between producing standard products, where economies of scale make them viable, and higher variability products that more closely match end-user needs.

To this end, an ontology for value creation is being developed. This ontology examines the interrelationships between a producer's supply chain (push production) (Fig. 3), with that of the end-user pull production approach (Fig. 4).

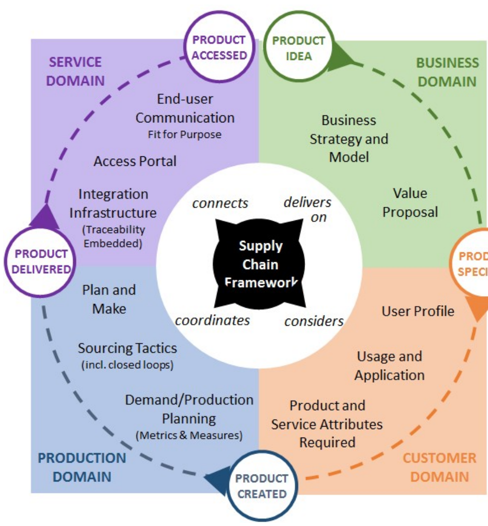

Fig 3. Data Producer Supply Chain Framework

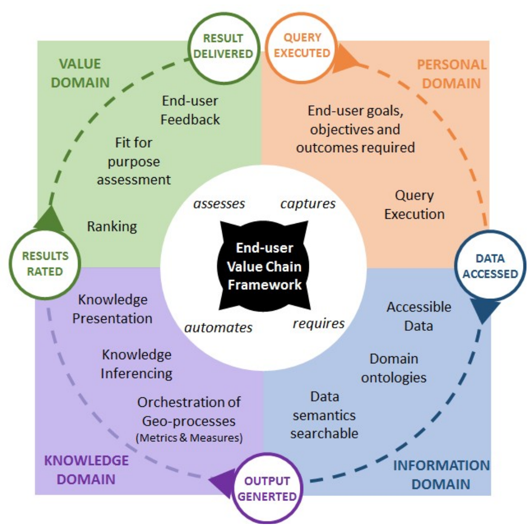

Fig 4. End-user Value Chain Framework

The *Supply Chain Framework* identifies those aspects of *Push* Production that combine to deliver a product to the end-user. It includes four domains: (a) the Business Domain, which captures an organization's strategy often directed at creating customer demand and reducing operational costs; (b) the Customer Domain, which gauges end-user requirements and purpose; (c) the Production Domain that focuses on planning, operational effectiveness and efficiency, and strategic sourcing; and (d) the Service Domain that provides open access to standard and tailored products, balanced with privacy.

Conversely, the *End-User Value Chain Framework* identifies those aspects of a *Pull* Production Supply Chain that combine to deliver knowledge to the end-user. There are four domains; (a) the Personal Domain that captures the goals and objectives of the end-user thus putting people and not business at the centre of requirements gathering; (b) the Information (or Spatial Resource) Domain that works for the people accessing data rather than for the producer's benefit; (c) the Knowledge Domain, which automatically orchestrates and manages the complex geospatial processes; and (d) the Value Domain, which assesses the trustworthiness of the supplied information against the user's goals and objectives.

From these frameworks, ecosystems for the supplier and user domains have been developed to organize the ontology variables and construct associations and interactions. The objective of the ontology is to understand: (a) at which point in the supply chain data should be made queryable so that the most benefit can be derived; (b) what tools and visualisation techniques can be recycled; (c) where methodologies and policy need to be adapted or enhanced to enable value creation; and (d) where production lead times and setup costs can be reduced in favour of a more dynamic approach.

4. MEASURING VALUE OF GEO-SPATIAL INFORMATION

The frameworks above do not consider information use, only the processes up to delivery and access, and associated *value* activities. While Return on Investment (ROI) measures and user satisfaction *feedback* mechanisms are included, the actual ontology needs to go one step further and incorporate measurements of value associated with social, economic and environmental decision making outcomes.

Estimating the value of information in the context of the user, necessitates an understanding of *to what degree a person (or business) values the knowledge they receive*. This requires a benchmark of the current state (without knowledge) to calculate the benefits gained in the future state (with knowledge), including tangible, intangible, financial and non-financial benefits.

Drawing on Value Theory, ethical value is intrinsic to decision making and as such, is an underpinning measure of value. Governments, businesses and people are often faced with choices that matter. In the case of bushfire; emergency responders need to know where to prioritize resources; governments want to know where to finance disaster mitigation works; insurance companies want to know whether to insure a home or not; and people want to know if they should stay to defend their property or leave early. In each case, there is a duty of care to others that creates an ethical dilemma.

Spatial information can help governments to determine the most ethical course of action and develop policy, such as declared fire risk zones, building codes and fuel load reduction programs. The right course of action is dependent on the reliability of information. So how much are governments willing to spend to get the right information and what is the impact of making the wrong decision? Ethical Value will be included in the ontology along with ethical indices, such as measures of poverty [8] to benchmark and calculate the value of spatial information.

5. CONCLUSION

The societal value of spatial information can be improved by providing end-users with the ability to pull at will the knowledge they need, when they need it. This calls for dynamic supply chains that can interpret a user's goals and objectives on-the-fly from a simple query. This approach is referred to as a Pull Production system and contrasts with traditional supply chains that push data out to the user and rely on pre-empting user needs. While the spatial analytics required to process a user query are proving complex to implement, the research effort is worthwhile. Today's society values being connected. Putting the user in control of their spatial information needs, rather than the supplier/producer, will be the new norm.

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Evaluation of geospatial data utilization for disaster governance in Uganda

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Keywords: **Geospatial, Disaster, Governance, Uganda**

1. INTRODUCTION

The need for spatially explicit information for disaster management in Uganda has gained elevated momentum over the last 10 years. A spatial inspection (Figure 1) reveals a myriad of recurring disaster inducing hazards, which are omnipresent across the country. The prominence of these hazards underpin the importance of harnessing geospatial data and its governance in order to protect the societies in a better way and obviate the economic impacts often linked to disaster events. Visibly, a significant concern in Uganda is directed toward landslides and flood hazards that are relatively fast and relatively complex to predict. The government of Uganda (GoU) has had a paradigm shift in disaster governance with a redirection from "*firefighting*" (response) to disaster risk reduction. The paradigm shift largely culminates from two processes (i) the engagement of the Hyogo Framework of Actions (HFA) 2005-2015 which stipulated certain activities and processes (ii) the recognition that managing risk is more economically and socially profitable than disaster response (iii) the stress emanating from increasing disastrous events notably the landslide of 2010 which killed over 300 people and the Kasese floods of 2013, which massively destroyed properties including loss of lives. Consequently, there has been an increased need to utilize geospatial data and information in governance for early warning activities, as well as in disaster risk reduction planning. Recognition of the importance of geospatial information in disaster governance has subsequently grown in Uganda owing to the above processes, but its utility remains suboptimal. It is therefore imperative to distill some of the intricacies underpinning geospatial data and information utility in disaster governance in Uganda, as reflected in case study presented herein albeit premised largely on qualitative analysis and synthesis.

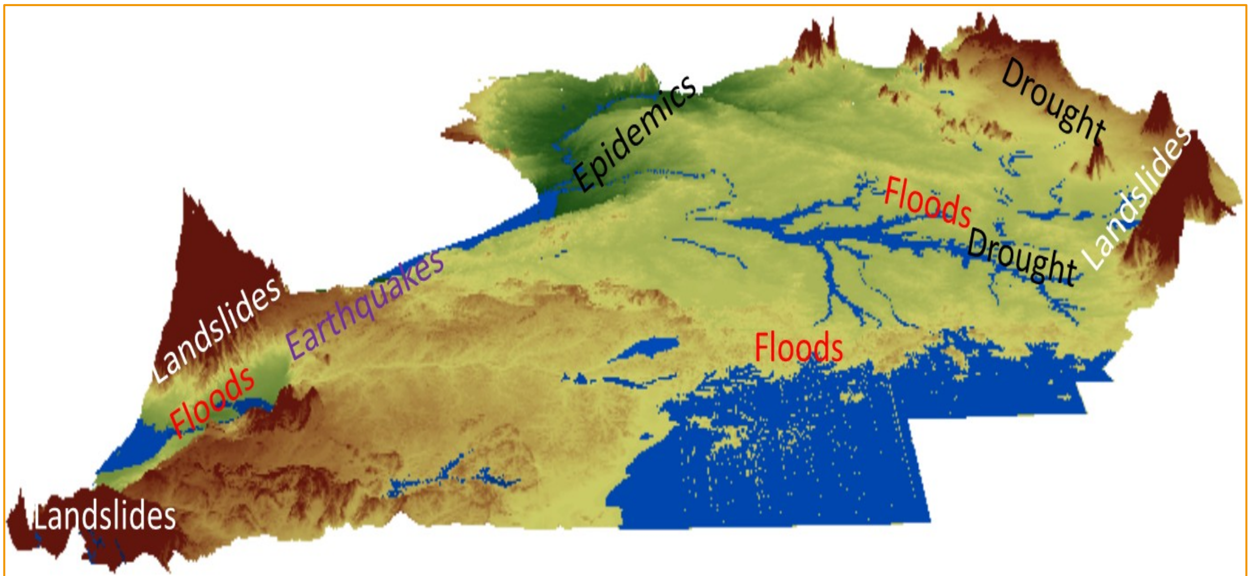

Figure 1: Spatial dynamic of major hazards which often translate into disaster events in Uganda

2. GOVERNANCE HIERACHIES AND GEO-INFORMATION FLOW PATHWAYS

The administrative structure of Uganda incrementally entails five layers i.e. (i) village (ii) parish (iii) sub County (iv) district (v) national level. Uganda at a size of 250,000km^2 is a highly districtilized country in a decentralized administrative structure currently consisting of 112 districts. Of these, about 50% are prone to disasters. An institutional framework (Figure 2) to facilitate interaction of the multiple administrative layers and disaster risk information flow upward and downward was developed.

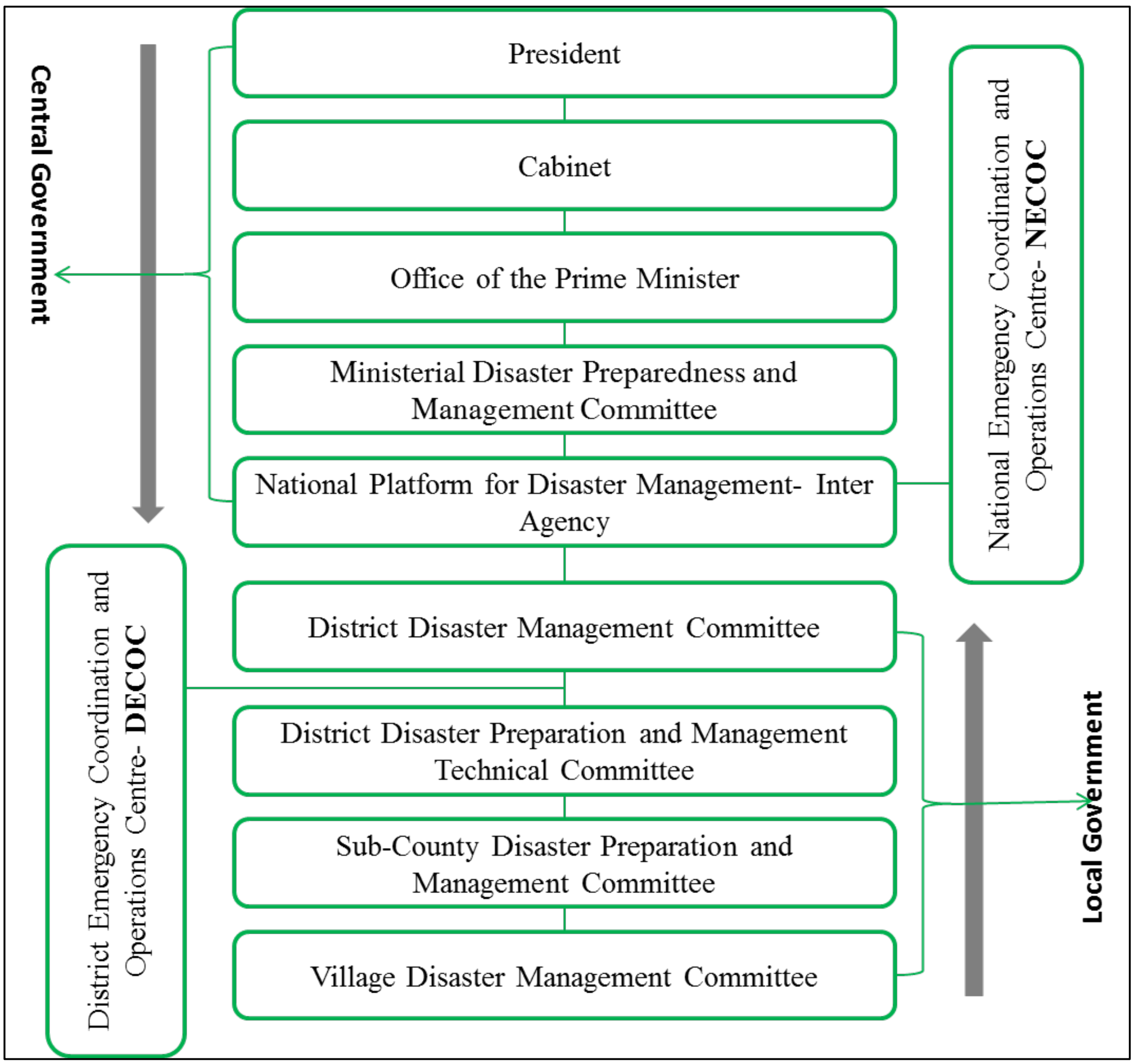

Figure 2: Idealized institutional framework to facilitate information and knowledge flow for disaster risk management in Uganda

The National Emergency Coordination and Operations Center (NECOC) was established in 2014 as a national facility to among others things facilitate better disaster risk reduction planning based on geospatial data and information. Part of the NECOC efforts in the improved geospatial data utilization involved installation of a GEONETCast facility that enables the reception of gigabytes of near real time digital satellite imagery data, which can be used in a wide range of disaster related applications. How far does this data trickle to the relevant administrative hierarchies for improved disaster risk management? Whilst substantial geospatial data is obtained at the national level, there are challenges both in its utilization at that level and transfer to the lower level administrative hierarchies required in effective disaster risk governance. Geospatial data utilization for disaster governance is still dismally low and highly centralized at national level, despite the fact that the general administrative structure is highly decentralized. But even at national level, its utility remains suboptimal largely focusing on NDVI applications, despite the reception of enormous near real time satellite imagery data. An investigation of the undermining factors reveals not only inadequate human and institutional capacities to also failure to optimize some of the existing human resource. Noteworthy also is the limited geospatial data utility by the civil organizations and NGOs despite their active involvement in disaster risk management. The geospatial data flow is currently unidirectional (top bottom) constraining the optimal realization of the intended benefits. These gaps in the chain of geospatial information utility have to be bridged if Uganda strategic goals in disaster risk management are to be realized.

3. MEASURING VALUE OF GEO-SPATIAL INFORMATION

The results based here are premised on synthesis and examination of qualitative data from various reports, interactions with relevant offices, scientific publications coupled with field experience of the disaster risk districts in Uganda and various interactions with key stakeholders in the national disaster risk reduction forum of Uganda. The existing gaps relate to quantifying the benefits across the administrative.

4. CONCLUSIONS

The idealized utility and importance of geospatial information in disaster governance is yet to be fully realized. The structural issues in Uganda's administrative hierarchies coupled with increasing districtilizations and weak capacities especially at the lower levels have been the major constraining factors in the higher realization of geo data benefits in this domain. Bridging the existing gaps through improved connectivity and information flow pathway will be critical in realizing the idealized benefits vis-à-vis the existing situation on ground.

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The Effect of "Pace of Onset" and "Administrative Scale of Environmental Hazards" on the End-User Value of Satellite Data for Environmental Decision-Making: A Contextual Analysis Based on Fieldwork in Central America, Africa, and the Himalayas

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Keywords: **SERVIR, pace of onset, administrative scale, Nepal, Guatemala, El Salvador**

1. INTRODUCTION

The increased frequency, severity, and variability of natural disasters and other environmental hazards brought about by global climate change have created significant need for accurate and timely environmental monitoring systems. Where ground-level monitoring capabilities are constrained by resources or terrain, satellite imagery provides decision-makers with a valuable alternative source of monitoring information. The utility and value of satellite information for decision-making is itself constrained by product limitations, obstacles to data access, and institutional barriers in end-user networks.

This paper examines two key parameters affecting the value of satellite data products for environmental decision-making: (1) pace of onset, and (2) administrative scale of the environmental threat in question. The paper posits that remote sensing data gains greater value when (a) event onset is slow or chronic, allowing time for information to move through the communications chain from processing to delivery to use; and (b) when the administrative scale of the event and decision-making context is large, outstripping capacity for ground-level data collection while increasing the need for observation of distant or remote areas.

This paper's analysis of pace of onset and administrative scale is placed within the context of the Regional Visualization and Monitoring System (SERVIR), a USAID/NASA collaboration that provides geospatial data tools and resources to countries in Central America, Eastern and Southern Africa, and the Hindu Kush-Himalaya to help these countries better manage climate risks, natural resources, and natural disasters.

2. METHODOLOGY

Findings are drawn from nine case studies conducted across seven countries as part of a 3-year USAID-funded performance evaluation of the SERVIR program. Each case study examines a unique geospatial tool developed by SERVIR in collaboration with one of three regional partnering hub institutions: the Water Center for the Humid Tropics of Latin America and the Caribbean (CATHALAC), located in Panama City, Panama, and serving the Central American region; the Regional Centre for Mapping of Resources for Development (RCMRD), located in Nairobi, Kenya, and serving Eastern and Southern Africa; and the International Centre for Integrated Mountain Development (ICIMOD), located in Kathmandu, Nepal, and serving the Hindu Kush-Himalaya region.

Case studies were selected according to three criteria. First, the evaluation aimed to capture cases in each of the three regions where SERVIR has been active in the past ten years. Second, cases were selected to include products employed across three broadly defined sectors: hydrology; natural disaster management and response; and land use, biodiversity, and ecosystems.

Finally, in order to properly measure impact, the evaluation team selected products believed to be of significant use in decision- making contexts.

The evaluation conducted a two-way tracer study to assess the use and impact of each tool. Guided by consultation with sector experts, the team traced the flow of information from initial dissemination of each SERVIR product to that product's institutional adoption and use, and where identifiable, its impact. For each case study the team then identified an appropriate event and traced the decisions driving the institutional responses, and the role of geospatial information in related decision-making processes. By identifying how geospatial data is used in decision-making contexts, the team was then able to consider value in terms of damages and losses averted, sector- or economy-wide impact, and the perceived value of SERVIR products in beneficiary communities.

3. MEASURING THE VALUE OF GEOSPATIAL DATA FOR ENVIRONMENTAL DECISION- MAKING IN DEVELOPING COUNTRIES

3.1. Use of Geo-Spatial Information for Environmental Decision-Making in Developing Countries

Under varying conditions, SERVIR's satellite data products are used toward distinct ends: to assess feasibility and/or viability for project planning, to inform early warning systems for rapid response, to mobilize public action, or to report on environmental status (e.g. greenhouse gas inventories). These products also perform an administrative function, complementing other sources of information, filling data gaps, and, in so doing, increasing data confidence for product users. Most commonly, satellite data is used by government or inter-governmental agencies to target priority areas for resource deployment and service delivery for disaster preparedness, mitigation, or response to environmental threats.

As observed across the nine case studies, the use of geospatial data products varies based on institutional capacity of the user as well as the suitability of a geospatial tool to serve its intended purpose. An important driver of product use, however, is a product's relationship to event timelines. SERVIR's geospatial data products are used in different ways depending on whether the decisions they inform occur prior to or following the onset of an event.

In pre-onset scenarios, geospatial tools can be used to monitor and/or model environmental conditions and thus inform service delivery and project implementation. Government agencies can target high-priority areas for resource allocation to mitigate the potential damage of a natural disaster. In Guatemala, for example, the national forest fire management network, known as the Forest Fire Prevention and Control System (SIPECIF), uses empirical risk models based on historical satellite data and other variables to position material and human resources for forest fire response. The Coupled Routing and Excess Storage model in Kenya and the JASON-2 Flood Forecasting and Warning System in Bangladesh, though not yet fully operational, are intended to model and predict flood height and extent in order to inform response activities.

In post-onset scenarios, SERVIR's geospatial products have proven useful for identifying damaged areas following large-scale disasters or other environmental calamities. Because decision-making in countries partnering with SERVIR is generally reactive rather than proactive, government agencies or other actors must prioritize allocation of limited resources in response to an event. In Nepal, for example, Normalized Difference Vegetation Index (NDVI) maps allowed World Food Programme (WFP) to assess inundation levels during 2014 seasonal flooding in four districts in Nepal's southern Terai region. As a result, WFP was able to prioritize distribution of limited relief supplies to the most affected areas.

In select cases observed by the evaluation team, products are used to guide frequency or location of other regular monitoring activity. In El Salvador, for example, daily maps of coastal chlorophyll concentrations inform decisions about when and where to test water and shellfish samples for evidence of toxic algal blooms. Likewise, in Nepal, NDVI indices inform site selection for ground-level crop monitoring missions conducted biannually in various locations across the country. In both cases, the respective satellite product influences monitoring behavior and aims to increase the efficacy of a comprehensive monitoring system.

3.2. Pace of Onset, Administrative Scale, and the Use of Geospatial Data for Environmental Decision-Making

The effect of pace of onset and administrative scale on the impact and value of geospatial data is closely linked with institutional realities in user networks for the products under review. Common institutional barriers to product use include lack of technical capacity, burdensome bureaucratic processes, and high rates of institutional turnover that limit institutional knowledge retention. These factors necessitate more time for response and a greater need for reliable geospatial data on large and/or remote areas where institutional presence is limited or absent.

Slow-onset events, such as drought, take more time to produce emergency conditions and are normally accompanied by early warning signs. Algal blooms in El Salvador and Guatemala and agricultural production shortfalls in Nepal are examples of slow- onset events observed by the evaluation team. Sudden-onset events, such as landslides, occur rapidly and with little or no advance warning. Rapid response mapping in Nepal, flooding in Bangladesh and Kenya, and forest fires in Guatemala are examples of rapid-onset events. The importance of this pace-of-onset distinction resides in the availability of satellite information and institutional capacity to absorb and process information. In some cases, such as rapid response mapping in Nepal, access required activation of time-consuming protocols.

The scenarios for SERVIR data-driven decision-making can be further delineated by the geographic scope of the event in question (and corresponding decisions that must be made in response). Across the nine case studies, SERVIR's tools proved most useful where the administration of the response to an event spans a geographically large administrative unit. Under large- scale scenarios, conventional (often ground-based) monitoring tools tend to be inadequate and prohibitively labor- or resource- intensive, creating a monitoring void that satellite imagery can fill. Under smaller-scale scenarios, on the other hand, decision- makers can rely on ground-level sources of information.

The evaluation team delineates between three relative degrees of localization. National or regional administrative responses occur within a large but unified administrative unit. Jurisdiction is consistent across the region and necessitates broad monitoring capabilities, to which satellite data is conducive. In a sub-regional context, decision-makers must monitor smaller but multiple administrative units within a regional jurisdiction. The example here is the Mid-Western region of the Terai in Nepal, where decision-making in response to seasonal flooding spanned several districts within the region, forcing responders such as WFP to prioritize distribution of scarce resources to those districts hit hardest by the floods.

Local or site-specific events, on the other hand, are contained within a geographically small and administratively unified area. Under such a scenario, such as in the Lake Atitlán watershed in Guatemala or in Kaski District in Nepal where flash flooding occurred in 2012, ground-level observation generally proves adequate for assessing and responding to environmental conditions.

Together, the timing and scale of event for which an earth observation product is designed influence a product's function and the impact that that product can have. Products that provide data for chronic or slow-onset events generally have a monitoring or detection function, providing stakeholders with warning that an event is in fact occurring. Where SERVIR products have been useful in rapid-onset events, on the other hand, namely in Petén, Guatemala, maps are effective for fire response because of quick access to and turnaround of MODIS data, the broad geographic proximity of the monitoring region, and exceptional institutional readiness to respond to fires during fire season. More often than not, in rapid onset situations SERVIR tools are not predictive and instead inform longer-term response or reconstruction.

3.3. Impact and Metrics for Measuring Value of Geospatial Data Products in Relevant Societal Benefit Areas

Through the case study approach, the evaluation team aimed to identify the mechanisms by which products, and the decision- making networks within which the products operate, impact beneficiaries at the ground level. For purposes of discussing impact, the evaluation team delineated benefit areas in terms of environmental, economic, and social benefits. A fourth category of impact, here referred to as administrative impact, also emerged through observation of product use.

3.3.1. *Environmental Impact*

Across the nine case studies, the evaluation team identified three types of environmental impact at least partially attributable to decisions based upon SERVIR's products or services: (1) averted ecosystem damages and/or losses, (2) preservation or restoration of threatened ecosystems, and (3) carbon sequestration. In the two former cases, impact is measured in terms of the value of ecosystem services. In the latter case, impact is measured as the stored value of carbon, in terms of net carbon sequestered if not also the expected monetary value of that carbon. Carbon sequestration is a desired outcome of Landsat- generated land cover maps in countries like Zambia, where not only is the country using maps in reporting forestry-related greenhouse gas emissions levels to the United Nations Framework Convention on Climate Change, but where provincial forestry officials have also used maps to identify highly deforested areas and initiate replanting activity.

Consistent environmental impact is strongest in the forestry sector and/or where land cover mapping is occurring. Hydrological products, such as flood monitoring and forecasting products in Bangladesh and Kenya, and products meant for disaster response outside the forestry sector have not yet had observable or measurable environmental impact.

3.3.2. *Economic Impact*

The evaluation team identified four types of economic impact fully or partially attributable to use of SERVIR's products and services. These include the following: (1) changes in market confidence, (2) property damages or losses averted, (3) increases in efficiency of service delivery, and (4) increased access to donor funds.

In terms of market confidence, the two water quality monitoring tools observed by the evaluation team, used in El Salvador and Guatemala, were developed in response to algal blooms, a problem with potentially significant negative economic repercussions for these countries' respective seafood, health, and tourism sectors. In the longer term, however, increased effectiveness of monitoring appears to positively affect market confidence. This is particularly the case in El Salvador. Evidence of market confidence was observed in fish markets on the coast and in the capital city, where both vendors and consumers expressed their trust in and willingness to abide by the national shellfish consumption bans during harmful algae bloom (HAB) events.

The evaluation team saw limited evidence of property damages and/or losses averted as a result of product use. This is largely because in some cases disaster-linked products are not completely rolled out, whereas in other cases the tool is strictly used for response rather than prevention (e.g. rapid response mapping for disasters in Nepal). Where economic damages and losses have been most clearly averted due to product use is in Guatemala, where improved fire management systems have meant lower likelihood of uncontrolled fires, timelier response, and greater likelihood of detection of remote fires.

3.3.3. *Social Impact*

While social impact is difficult to disaggregate from environmental and economic impact, the evaluation team identified three types of impact uniquely relating to social well-being: (1) environmental sensitization or behavioral impact, (2) preservation of cultural and environmental heritage, and (3) improved community health.

Satellite imagery powerfully visualizes environmental conditions, often allowing for a strong sensitization effect in beneficiary communities. That said, the sustainability of behavioral shifts are largely a function of product integration into user institutions. For example, at Lake Atitlán in Guatemala, imagery of the lake's algal bloom galvanized public opinion in response to a single event, but sustained momentum toward improved water management practices in the lake community has waned over time. In Petén, on the other hand, satellite imagery is fully integrated in fire management systems and regularly used. As a result, community agricultural practices and attitudes about forest fires are improving over time.

Concerning health impacts, the evaluation team could not observe direct improvements to community health as a result of product use. In El Salvador, expert testimony indicates that the red tide monitoring tool has contributed to decreased risk of cyanobacteria poisoning by contributing to decreased consumption of contaminated fish. But such health outcomes are difficult if not impossible to verify in that context due to lack of reporting and difficulties diagnosing the cause of food-borne illnesses.

3.3.4. *Administrative Impact*

Administrative impact captures the degree to which product use increases the administrative efficiency of stakeholders in a particular sector without independently driving stakeholder decision-making. In El Salvador, for example, satellite imagery of chlorophyll concentrations off El Salvador's Pacific coast assists the country's Red Tide Monitoring Commission with targeting water and shellfish testing at select locations along the country's coastline. The imagery increases confidence in the precision and accuracy of the commission's more comprehensive monitoring system, facilitating more cost-effective use of government resources for alternative monitoring methods.

3.4. Gaps in Measuring the Value of Geo-Spatial Data

The evaluation team encountered key obstacles in measuring the impact and value of SERVIR's geospatial products, including:

- Attribution: Impact cannot be exclusively attributed to product use. In all cases SERVIR plays a contributing role in generating impact as part of a larger decision-making system. The product may increase data confidence by filling data gaps or complementing other sources of information but it cannot assume sole credit for the decisions or their impacts.
- Challenges measuring administrative impact: Administrative gains accrue due to better access to data and improved capacity for using data in decision-making. These gains are difficult to measure for a number of reasons, not least of which is the fact that institutions are not always transparent regarding their own data gaps, data confidence, or the shortcomings of alternative monitoring methods.
- Lack of a proper counterfactual: The impact of SERVIR's geospatial data products is invariably shaped by any number of other contextual factors, including severity of an event, effectiveness of response and availability of alternative sources of information. Ideally the evaluation team would compare an event where a product was used with a comparable event where the product was not used. Because of the uniqueness of each event, no such counterfactual exists.

Due to these limitations, the evaluation team is in the process of measuring product value to beneficiaries in Guatemala and Nepal through choice experiments designed to measure respondents' willingness to pay for SERVIR's products. The results and limitations to these studies will be discussed in a separate forum.

4. CONCLUSIONS

The scenarios examined by the SERVIR evaluation team highlight important limitations to the power of satellite data to inform response. The first limitation is a lag in product delivery where information is needed rapidly. This lag, due to both product constraints and institutional barriers, is not without exceptions. Products such as the JASON-2 Flood Forecasting System in Bangladesh are being piloted to manage site-specific rapid-onset events. This system is anticipated to see more widespread use as it increases its predictive accuracy over time. The second limitation is one of scale. Geospatial data assumes great significance in large-scale and difficult-to-access areas under the management of a single administrative unit. Again, there are exceptions to this condition. Of note, satellite imagery is a powerful tool for public communication and can persuade communities of the presence of calamity where calamity may not be immediately visible, even when confined to a small locality.

The evaluation team finds great value in the targeting function of SERVIR's data products. Indeed, this function is highly conducive to slow-onset, large-scale events, where conditions can be assessed and resources allocated over large geographic regions or across administrative borders. At the same time, underlying the contextual limitations brought by pace of onset and administrative scale are the institutional factors that preclude developing institutions from effectively integrating and using geospatial technology. SERVIR's products increase administrative efficiency and data confidence and thus have a significant role to play in strengthening user institutions.

Fitness-for-use of geospatial information products: uncertainty and value

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ABSTRACT: Spatial data quality has been a topic of research for several decades but the usefulness of spatial data quality parameters needs to be improved to enable valuation of geospatial information in real-world applications. In this paper we list a variety of studies focussing on methodological aspects of fitness-for-purpose assessments as well as case studies in this research field. Relevant methods involve error modelling accounting for spatial correlation of map errors, propagation of input uncertainties through models, and the expected value of information (EVOI) for ex-ante assessment of the value of geospatial information products. We finish by underscoring the need for comprehensive and convincing studies on valuation of geospatial information for complex socioeconomic decision making.

***Keywords*: Spatial correlation, uncertainty propagation, expected value of information, cost functions.**

1. INTRODUCTION

While spatial data quality (which aims to assess or ascertain fitness-for-purpose) has been a topic of research for several decades, the usefulness of spatial data quality parameters in real-world applications still needs to be improved. Some spatial data quality parameters (e.g. semantic accuracy) may not be understood by users of geospatial products, terms are used inconsistently (e.g. accuracy, precision) and reporting quality parameters is sometimes perceived as a needless burden. On the other hand, commonly reported parameters may fail to address specific user needs or they are insufficient to allow valuation of geospatial information in real-world applications. For example, recently we experienced a lack of information on spatial correlation of errors in the inputs needed to assess greenhouse gas emissions. Such information is crucial for assessing prediction intervals of emissions over larger administrative units, e.g., within the context of REDD+ implementation (REDD+ stands for countries' efforts to Reduce Emissions from Deforestation and forest Degradation, and foster conservation).

Over the past years we have done various studies on several aspects of fitness-for-purpose assessment. In this extended abstract we summarize some of that work along with underlying methods and identify needs for further research.

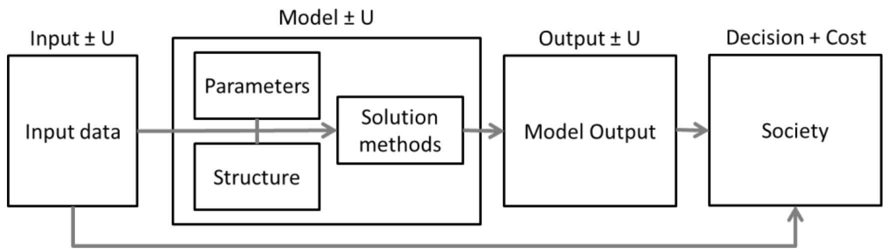

Fig. 1: Using geospatial information products for decision making; U denotes uncertainty.

2. METHODS

Figure 1 provides a conceptual overview of steps involved when using geospatial information products for decision making. Input data are either used directly or they are first processed using a model providing output that is subsequently used for decision making. The leftmost three blocks involve uncertainties. We are unsure about the true state of the environment since we only have measurements or map representations which are error-prone. Input uncertainties propagate through all later steps. Any intermediate process model adds uncertainty because parameter values are estimated rather than known, there are errors in the model's structure and because of inaccuracy of the used solution methods. These uncertainties affect decision making in the rightmost box of Figure 1, where they turn into costs. More accurate information allows more informed decision making, resulting in cost reductions and hence producing societal benefits (Bernknopf and Shapiro, 2015). We are interested in the expectation of these reduced cost.

2.1. Uncertainty

2.2.1. Input error

An error in a quantitative attribute can be defined as the difference between the reality and a representation or measurement. Not knowing the true error, the best we can do is to specify a distribution of possible values; this distribution expresses the concept of uncertainty. In our work we have focussed on probabilistic models in which error is modelled by a random variable. Nearby errors in spatial or spatio-temporal datasets are often correlated. Such correlation is conveniently modelled using a variogram (Heuvelink, 1999). It is important to take spatial or space-time correlation into account, particularly when uncertainties are aggregated since independent errors tend to cancel each other over larger spatial entities. In contrast, dependent errors cancel out to a lesser extent. On the other hand, a sparse sample of a spatially correlated measured errors is more informative than a sample of uncorrelated measured errors (de Bruin, 2000).

2.2.2. Model uncertainty

For linear models, propagation of input uncertainty is readily computed. Otherwise, if the analysis or process model is partially differentiable with respect to its inputs, a truncated Taylor series approximation method can be used to approximate the model centred at the expected input values. This greatly simplifies the analysis of input uncertainty propagation, at the expense of introducing an approximation error. Otherwise, Monte Carlo simulation is a popular approach. The idea of the latter method is to compute the model result repeatedly, with input values randomly sampled from their joint probability distribution (Heuvelink, 1999). Uncertainty about model parameters and model structure can be assessed by Bayesian calibration (Kennedy and O'Hagan, 2001) using a sample of observational data.

2.3. Decision making

The expected value of information (EVOI) is estimated as the difference between expected costs when making rational decisions at the present stage of knowledge and the expected costs when decision making is based on new information that reduces uncertainty (Morgan and Henrion, 1990). In other words it expresses the expected benefits that result from making more informed decisions. Bernknopf and Shapiro (2015) refer to it as *innovation applications*.

The method is explained by an example (de Bruin et al., 2001). Figure 2(a) shows a simplified decision tree for choosing either a current digital elevation model (DEM), A, or an updated version, B, for computing the volume of sand required for building a container port. The bell-shaped curves in the boxes depict the probability density of error in the determined volume of sand, conditional to the chosen DEM. Figure 2(b) shows a cost function for incorrect purchases of sand. A rational (or Bayes) decision corresponds to the purchase that minimizes the costs integrated over the corresponding probability distribution. The expected value of information of DEM B equals the difference between the expected costs of the Bayes decisions for both DEMs.

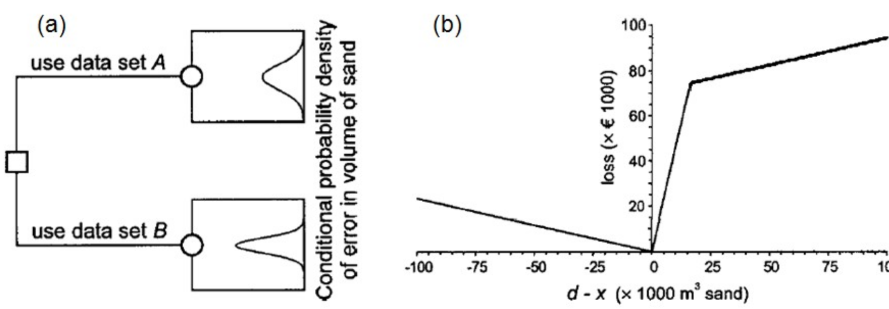

Fig. 2: Simplified decision tree for choosing between two digital elevation models (a) and cost function (b). Source: de Bruin et al. (2001).

3. EXAMPLE RESULTS

Figure 3 and Table 1 present results obtained by —at least partially— running through the steps depicted in Figure 1. Table 1 (from Roman-Cuesta et al., *in prep.*) provides a notable example of the lack of information if spatial correlation of map errors is unknown. Assuming complete spatial dependence of the pixels within aggregates, the coefficient of variation of CO_2 equivalent greenhouse emissions attributable to Agriculture, Forestry and Other Land Use (AFOLU) aggregated to tropical and continental scale were 34 to 75 times higher than if complete spatial independence was assumed. Reality will be somewhere in between, but where? The required spatial correlation function (or variogram) can be computed from reference data, if available. Absence of knowledge about spatial correlation considerably limits the usefulness of the AFOLU emission data within the context of REDD+ implementation, where countries may receive payments for decreased CO_2 emissions (Sandker et al., 2010). Estimation of the expected loss owing to this absence of information would require information on payment schemes and the societal costs of greenhouse gas emissions.

Table 1. Uncertainty about AFOLU emissions over large regions under two scenarios

Region	Coefficient of variation (%)	
	Independent	Complete
Tropics	0.4	30
Central & South	0.7	36
Africa	0.4	25
Asia	0.8	27

Figure 3 is taken from Heuvelink et al. (2010). It shows the results of a geostatistical methodology to optimize the allocation of mobile radioactivity measurement devices during a simulated emergency event, such that the expected weighted sum of false- positive and false-negative areas (i.e. false classification into safe and unsafe zones) is minimized. The weights were determined by the relative costs of two types of misclassifications. While here the objective was sample allocation rather than determination of the value of information, the approach follows all steps indicated in Figure 1, hence demonstrating feasibility of the approach. However, for valuation of the geospatial dataset produced using the measurement devices, absolute rather than relative costs are required. These were used for the example presented in section 2.3.

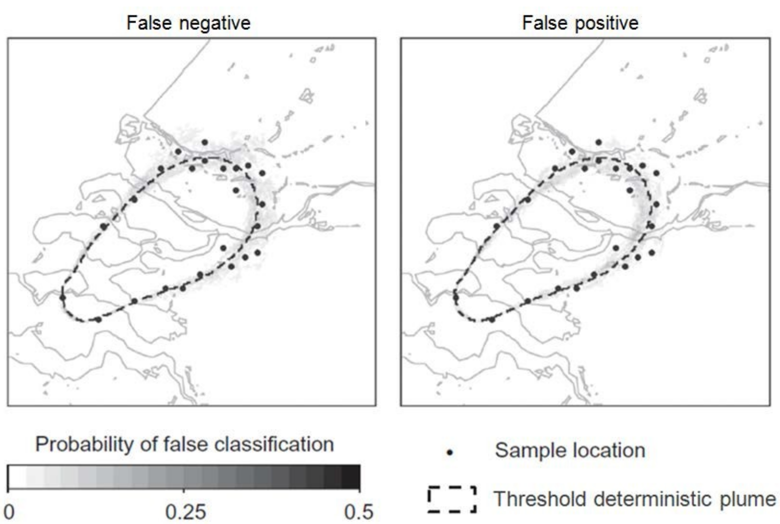

Fig. 3: Optimized sampling design for the allocation of mobile radioactivity measurement devices during a simulated accident at the Borssele nuclear facility in the Netherlands. Source: Heuvelink et al. (2010).

4. MEASURING VALUE OF GEOSPATIAL INFORMATION

Assessing the value of geospatial information requires information on the spatial correlation of errors in the dataset. If such information is unavailable, valuation of the information at the level of individual support units (e.g. points or pixels) is possible, but erroneous results are obtained when aggregating to larger spatial units. Furthermore, functions describing the costs or utility of events that may occur under uncertainty are indispensable for the valuation of geospatial datasets. Heuvelink et al. (2010) and de Bruin et al. (2001) presented examples where (relative) cost functions were easily obtained. However, ongoing research on greenhouse gas emissions has shown that societal costs and utilities in more complex problems may be hard to quantify. Nevertheless, REDD+ implementation depends on geospatial information and it provides a compelling case for assessing the value and socioeconomic impacts of geospatial information for decision making.

5. CONCLUSIONS

- Methods for assessing the value and socioeconomic impacts of geospatial information for decision making are available.
- Information on the spatial correlation of errors in the geospatial dataset is essential for most assessments.
- Data on costs and utilities in decision problems are indispensable.
- REDD+ provides a compelling case for assessing the value and socioeconomic impacts of geospatial information.

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ESA use of satellite derived information for ecosystem service assessment

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ABSTRACT: At its simplest, the estimation of socio-economic benefits of ecosystem services breaks down into two components – the characterization of the extent to which an ecosystem provides a certain level of a specific service and the estimation of the extent and value of the benefits resulting from the level of service provided. The first component generally requires a set of biological, chemical or physical measurements of the components of the ecosystems of interest while the second component is based on economic modeling. This is difficult enough but in many situations the actual requirements are more exacting in particular, it is often required to measure the impact of a particular activity in terms of changes in value of ecosystem services in areas affected by the activity in question. Before any economic assessment can be conducts, this requires an accurate delineation of the extent of the changes to ecosystem component s caused by the activity of interest and an assessment as to how such changes impact on the capacity of the ecosystems of interest to provide a particular level of service.

There is an increasing level of interest in the potential use of satellite data to support the estimation of spatial and temporal changes in components of ecosystems (e.g. habitat structure, water quality) within ecosystem service assessment. Traditionally satellite Earth Observation has been used to derive basic geographic parameters (e.g. land cover classification, sediment concentration etc.) at relatively low sampling frequencies (e.g. annual or seasonal status for land cover, monthly p90 concentrations for coastal sediments etc.). These parameters were then used as inputs to models which characterize the status of particular habitats as well as the associated pressures on these habitats. This was then used as the basis to assess the status of a particular ecosystem and its capacity to provide certain ecosystem services. As such this was quite a limited use of satellite derived information.

Over the last 5 years however, a range of step improvements have combined to change the extent to which satellite Earth Observation can contribute to ecosystem assessment. New observation techniques (e.g. long wavelength imaging radar, new spectral infra-red bands), radical improvements in sampling frequency (e.g. an image of the total Earth land surface every 5 days with Sentinel 2), new processing algorithms (e.g. polarimetric InSAR) and access to improved computing power are opening up new possibilities to make wider use of satellite EO derived information for characterizing ecosystems.

This presentation will illustrate results to date and some of the capabilities and on-going initiatives where ESA is supporting wider use of EO derived information for characterizing the status of ecosystems with a view to improving methodologies for ecosystem service assessment, natural capital estimation and landscape valuation.

Data to Decisions: Valuing the Societal Benefit of Geospatial information in case of Disasters such as Earthquakes and Tsunamis

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ABSTRACT: The issue of how to convert data to information and then to decision is applied it to Chilean application tool. Within the Architecture Implementation Pilot (AIP) project, Capacity Building Working Group (CB WG) that I'm coordinating, we have selected seven test pilot areas related to earthquakes, tsunamis, volcanic eruptions and fires.

We are applying a service oriented architecture (SOA) that allows each agency (national of international) to manage its own data silos, however each agency agrees to make the metadata of those data available through web services according to a GEO Common Infrastructure (GCI) platform that is interoperable according to OGC (Open Geospatial Consortium) and ISO (International Standard Organization) geospatial standards.

At the present time, there are main groups working on developing a client application that is accessing, searching and discovering the GEO portal and GEO web services: one group is focused on developing metadata to enlarge and integrate the GEO Chile Portal, managed by IDE-SNIT; another group is working on the developing data imagery, mostly coming from the satellite EO-1, from the Chilean satellite agency, and other imagery activated during disasters; a third group is working on developing the client application tool. Other three groups are however coming in: one related to establishing for the testing areas, the land use; another for developing socio-economic-physical- environmental models related to the latest 8.3 moment magnitude-16 September, 2015 earthquake in Illapel; and a group related to telecommunications during emergencies events in Chile.

In 2016, we look to capture the geographic diversity and increase the resilience to disasters of Chile, by developing a model for evaluating the socio-economic impact of web services, in order to allow emergency personnel, regional authorities and others, to optimize their decisions in relation to the characteristics of the disasters.

In this paper, I plan to consider initially earthquakes and tsunamis to promote feedback and possible collaboration between the communities stricken by a disasters and the decision makers. I suggest to prepare at least one matrix related to the data supplied by the Data Producers versus GEO Users (made them anonymous). Each different matrix will be related to the different stages in which a decision maker will be in the disaster cycle Of course, the accuracy of each dataset will be reported in each relative metadata.

Another matrix will consider the Data Producers versus the GEO Users feedback, including the social media feedback, in terms of the some parameters, such as the number of downloads, or uploads (since a GEO User can become a Data Producer), and some socio-economic parameters. Other statistical analysis are presented for type of disasters, and scenarios, regarding both people, pets, livestock and land use. Aspects of spatial variability are

also discussed. In order to develop the decision-based model, a survey and/or a feedback form has been attached to the GEO disaster client application tool.

***Keywords*: socio-economic, values, geospatial, web, services.**

1. INTRODUCTION

Chile has some of the costliest natural disasters in the world (the death toll was 500 people and the cost of an earthquake in 2010 amounted to about 30 billion USD, Fig. 1 and Fig. 2, [1]).

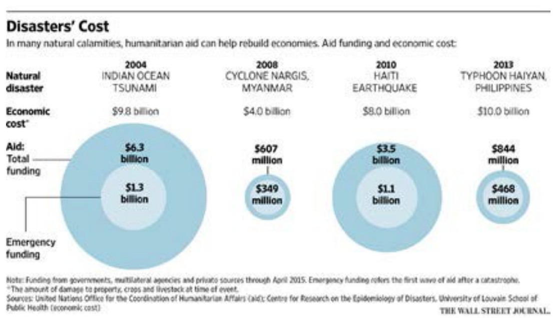

Fig. 1: Cost of some natural disasters

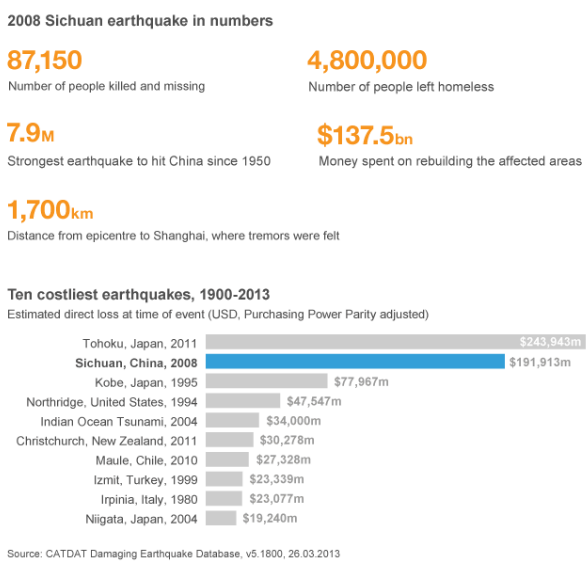

Fig. 2: Costliest earthquakes as of 2013. Here, the Maule or Talcahuano earthquake, Chile is shown as having a cost of about 28 billion USD.

The issue of how to convert data to information and then to decision is applied it to Chilean application tool. Within the Architecture Implementation Pilot project, Capacity Building Working Group that I'm coordinating, we have selected seven test pilot areas related to earthquakes, tsunamis, volcanic eruptions and fires. We are applying a service oriented architecture (SOA) that allows each agency (national of international) to manage its own data silos, Each agency agrees to make the metadata of those available through web services according to data sharing principles [2] and a GEO Common Infrastructure (GCI) platform that is interoperable according to geospatial OGC and ISO standards.

At the present time, there are main groups working on developing a client application that is accessing, searching and discovering the GEO portal and GEO web services: one group is focused on developing metadata to enlarge and integrate the GEO Chile Portal, managed by IDE-SNIT; another group is working on the developing data imagery, mostly coming from NASA satellite EO-1, and the Chilean satellite agency, as well as other imagery activated during disasters; a third group is working on developing the client application tool. Other four groups are coming in from 2016 on: one group is related to establishing the land use for the testing areas in Chile; another for developing socio-economic-physical-environmental models related to the latest 8.3 moment magnitude-16 September, 2015 earthquake in Illapel, Chile; and a group related to telecommunications during emergencies events in Chile.

In 2016, we look to capture the geographic diversity and increase the resilience to disasters of Chile, by developing a model for evaluating the socio-economic impact of certain decisions, in order to allow emergency personnel, regional authorities and others, to optimize their decisions in relation to the characteristics of the disasters.

We consider that the life cycle of risk management for disasters areas is mainly characterized by three phases: prevention, response, and recovery. In the Chile AIP-GEOSS project, these three phases of disasters are considered within a GEOSS framework for metadata and geospatial data web services. For each area, four levels of alerts are used: green, yellow, amber, and red. At the amber alert level, the mobilization of people exposed to a disaster is triggered, and people are evacuated. The Chilean emergency agency, ONEMI, makes broadcasts of alerts and notifications using all means, including radio, VHF, and social media.

In this paper, I plan to consider initially earthquakes, and tsunamis to promote feedback and collaboration between the communities stricken by a disasters and the decision makers. I suggest to prepare at least one matrix related to the data supplied by the Data Producers versus GEO User (made them anonymous) within the geospatial web services framework. Each different matrix will be related to the different stages in which a decision maker will be in the disaster cycle: prevention, response, and recovery. The overall accuracy of the Data Producer- GEO User matrix will represent either the information coming from the testing areas, and/or the feedback coming from the GEO Users. Of course, the accuracy of each dataset will be reported in each relative metadata. Another matrix will consider the Data Producer versus the GEO User feedback, including the social media feedback, in terms of the some parameters, such as the number of downloads, and some socio-economic parameters. Another matrix will present testing of the social impact during a disaster with respect to the alert levels and the medium through which the alert is sent out and received. Other statistical analysis are presented for type of disasters, and scenarios, regarding both people, pets, livestock and land use. Aspects of spatial variability are also discussed. In order to develop the decision-based model, a survey and/or a feedback form was attached to the GEO disaster client application tool.

2. OBJECTIVE

I consider initially earthquakes, and tsunamis to apply a socio-economic model to give GEO variables that are extracted from the GEO Portal and are related to different phases of the disaster cycles for earthquakes and tsunamis. The paper will focus on Chile disaster events of approximately five years.

3. DATA AND STUDY AREA

The used data and web services are relative to seven testing areas in Chile. They are respectively, Talcahuano, interested by an earthquake and tsunami in 2010; Iquique, in northern Chile, were an 8.1 earthquake partially ruptured a fault; and Illapel earthquake, in central Chile, where an 8.1 moment magnitude earthquake occurred on September, 2015. The other areas are active volcanic regions (Copahue, Villarrica, Calbuco) and an area --Valparaiso -- were wildfires occurred. In all these regions, up to 3,000 inhabitants had to be evacuated by the Chilean disaster agency, ONEMI.

4. MEASURING VALUE OF GEO-SPATIAL INFORMATION

In this paper, I suggest to prepare at least one matrix of related to the data supplied by the Data Producer versus Data User (made them anonymous). Each different matrix will be related to the different stages in which a decision maker will be in the disaster cycle. The overall accuracy of the Producer-User matrix will represent either the information coming from the testing areas, and/or the feedback coming from the GEO Users. Of course, the accuracy of each dataset will be reported in each relative metadata. Another matrix will consider the Data Producer versus the GEO User feedback, including the social media feedback, in terms of the some parameters, such as the number of downloads, and some socio-economic parameters. Another matrix will present testing of the social impact during a disaster with respect to the alert levels and the medium through which the alert is sent out and received. Other statistical analysis are presented for type of disasters, and scenarios, regarding both people, pets, livestock and land use. Aspects of spatial variability are also discussed. In order to develop the decision-based model, a survey and/or a feedback form was attached to the GEO disaster client application tool.

Fig. 3: Records retrieved from GEO Portal at http://www.geoportal.org/web/guest/geo_home_stp

We looked at the geoportal, shown in Fig. 3, and selected the Disasters Social Benefit Area: 1087 records were returned, of these records, 216 are related to Chile, Disaster Societal Benefit area for the last five years.

For earthquakes, the following variables are discovered and identified in the GEO portal: File Identifier, Parent Identifier, Hierarchy Level, Data Stamp, Contact Information, Identification Information (Title, Description, Descriptive Keyword), Constraints, Legal Constraints, Security, Content Information, Geographic Extent (South, West, North, East), Temporal Extent (Start, End), Distribution Information (Online resource, Description, Name, Linkage, Protocol).

Since we are working on the second version of a client-application that uses both Chilean Catalog Service for the Web Service (CSW) maintained by the Chilean agency IDE-SNIT [3], and the international earthquake web services catalogue from IRIS [4], also registered via GEO DAB on the GEO portal, I developed a model to establish machine-calculated value matrices of web services that address specifically the following:

• Accuracy that is defined as the error rate generated by geospatial web services;

• Performance that represents how fast a service request can be completed;

• Reliability that represents the ability of web services to perform its required functions under stated conditions for a specified time interval.

There are other value-added estimates related to the geospatial web services, such as security, scalability, capacity and others, but here I concentrate on establishing the accuracy of geospatial web services.

Within each phase of the disaster cycle (prevention, response, and recovery) and considering that we consider four level (including an amber alert), a matrix is built that has on the y-axis one or more GEO-User and on the x-axis one or more Data Producer (in case we consider the Chaining Web Services). The variables are the ones presented in the GEO portal and mentioned above.

For the accuracy matrix, I consider the following variables, for each web service (considering the Linked data): File Identifier, Parent Identifier, Hierarchy Level, Data Stamp, Contact Information, Identification Information and Geographic Extent.

For the performance matrix, I consider the following variables, for each web service (considering the Linked data): File Identifier, Parent Identifier, Hierarchy Level, Data Stamp, Contact Information, Identification Information and Temporal Extent.

Another matrix will consider the Data Producers versus the GEO Users feedback, including the social media feedback, in terms of the some parameters, such as the number of downloads, or uploads (since a GEO User can become a Data Producer), and some socio-economic parameters.

Of course, since we plan to consider it in the Chilean application version that we are developing, there will be some changes in relation to our results and we'll report it to the geospatial community.

5. CONCLUSIONS

I've started to present here a model for evaluating the socio-economic impact of web services as we are developing in a client application that consider Chilean web services along with other web services within GCI (GEO Common Infrastructure). According to a set of matrices, we calculate some metrics related to the accuracy, performance and other socio-economic parameters that will allow emergency personnel, regional authorities and others, to optimize their decisions in relation to the characteristics and phase of each disaster event in the testing areas of Chile.

In this extended abstract, I suggest to prepare at least one matrix related to the data supplied by the Data Producers versus GEO Users (made them anonymous). Each different matrix will be related to the different stages in which a decision maker will be in the disaster cycle Of course, the accuracy of each dataset will be reported in each relative metadata.

Another matrix will consider the Data Producers versus the GEO Users feedback, including the social media feedback, in terms of the some parameters, such as the number of downloads, or uploads (since a GEO User can become a Data Producer), and some socio-economic parameters. Other statistical analysis are presented for type of disasters, and scenarios, regarding both people, pets, livestock and land use. In order to develop the decision-based model, a survey and/or a feedback form has been attached to the GEO disaster client application tool.

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The Not-so Marginal Value of Weather Warning Systems

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ABSTRACT: Estimates of the causal impact of programs are important for determining the optimal levels of investment. Yet estimates of the causal impacts of weather warning systems are sparse, perhaps because there is often no clear counter-factual of how individuals would have fared without a particular warning system. This paper enriches the literature and informs policy decisions by using conditional variation in the initial broadcast dates of the National Oceanic and Atmospheric Administration's Weather Radio All Hazards (NWR) transmitters to produce both cross sectional and fixed effects estimates of the causal impact of NWR transmitters. Results suggest the presence of a NWR transmitter causally reduces injuries by almost 40% and fatalities by as much as 50%.

***Keywords*: weather warning systems, geo-spatial identification strategies, causal identification, tornadoes**

1. INTRODUCTION

From 2004-2013, weather-related hazards caused over 600 fatalities and 3,300 injuries per year in the United States. Tornadoes exceed hurricanes as the leading cause of storm-related deaths and injuries in the U.S., accounting for 1,091 fatalities and 12,407 injuries over this window (U.S. Natural Hazard Statistics, http://www.nws.noaa.gov/om/hazstats.shtml). Healy and Malhorta (2009) report that from 1985-2004, the United States federal government spent $195 million per year on disaster preparedness. It is often argued that disaster preparedness is woefully underfunded in the sense that the number of deaths and injuries prevented per dollar exceed the returns on many other government investments purportedly targeted at saving lives. To date this claim has been largely speculative due to the lack of robust statistical evidence regarding the benefits of weather warning systems. This paper contributes to the literature by showing how temporal and geo-spatial variation in the availability of warnings can be used to provide causal estimates of the impacts of a weather warning system.

There are a large number of case studies and household surveys examining how individuals responded to severe weather warnings. While this literature very useful for understanding how individuals respond to existing warning systems, the counter- factual is not clear. How would people have fared without a particular warning system? If warnings from a NOAA weather radio were not available, would individuals have received and responded to warnings from a siren, television, or phone? Perhaps different warning systems convey different information which impacts how effectively individuals protect themselves.

This paper addresses the difficulty in obtaining a reliable counter-factual by exploiting variation in the initial broadcast dates of the radio transmitters for the National Oceanic and Atmospheric Administration's Weather Radio All Hazards (NWR). Because the timing and location of these installations is non-random, two different identification strategies are used to estimate the causal impact of NWR broadcasts on tornado deaths and injuries. The first is a cross-sectional comparison of deaths and injuries across a sample of more than 23,000 tornadoes. The second method is a county-level fixed-effects analysis which examines how fatality and injury rates change after broadcasts begin.

Focusing the first impact evaluation of a weather warning system on NWR is appropriate for several reasons. In addition to the availability of quality data and a clear source of identifying variation, NWR has long been a flagship warning system of the National Weather Service. More broadly, this research intended to point the way for further revealed preference impact evaluations in studying how to mitigate the damages from severe weather events. Given the geo-spatial nature of these events, strategies which consider and exploit geo-spatial information can produce valuable insights, informing the decisions of policy makers and improving the outcomes of individuals.

2. BACKGROUND

2.1. The History of NWR

NWR is a network of radio stations which broadcast weather information from the nearest National Weather Service (NWS) office. The first NWR transmitters were installed in New York City (Jan. 1, 1953) and Chicago (Apr. 1, 1953) to broadcast aviation weather. After aviation broadcasts moved to L/MF radio stations, the stations became available for marine service. During 1966 and 1967, nine additional coastal stations were added to support the maritime community. Partially in response to a

``Super Outbreak" of 148 tornadoes in the 24 hour period in April of 1974, a January 1975 White House policy statement designated NOAA Weather Radio as the sole government-operated radio system to provide direct warnings into private homes for natural disasters. The prevalence of NWR transmitters has expanded over time, and now covers most of the United States.

2.2. Current Literature

A large number of case studies and surveys examine how individuals respond to warnings in various situations. Balluz et al. (2000) found that roughly 45% of those who responded to a random telephone survey following March 1, 1997 tornadoes in Arkansas reported seeking shelter after learning of the tornado warning. Liu et al. (1996) survey in two Alabama areas after tornado warnings to learn the type of warning respondents heard first. Dow and Cutter (1998) survey residents about how they responded to repeated hurricane evacuation orders over the course of a single season. Case studies such as these are immensely helpful in determining what warnings individuals hear and how those warnings are perceived. But they are not helpful for determining the causal impact of warning systems, because they often suffer from serious selection bias problems and the counter-factual is unclear. This paper shows that geo-spatial variation can be used to answers a different and critical question: How would people have fared without a particular warning system?

While there has been little writing on the causal impact of warning systems directly, some papers have attempted to estimate the causal benefits of warnings themselves. Doswell et al. (1999) show that shortly after the beginning of public tornado forecasting there was a reduction in deaths relative to inflation-adjusted damage from major tornadoes. Improvements in forecast ability also matter. Simmons and Sutter (2008) find that longer lead times on tornado warnings reduce injuries, and Simmons and Sutter (2005) find that the installation of Doppler radar in the 1990's reduced fatalities and injuries by 45% and 40%, respectively.

Sutter and Simmons (2014) find no measurable impact of tornado watches (issued when conditions are favorable for tornadoes) beyond the benefits already granted by warnings. Current work by Bakkensen (2015) finds warnings are more effective before sundown because individuals are able to personally observe the storm.

3. DATA & METHODOLOGY

3.1. Data

This paper uses data from the Storm Prediction Center's national tornado archive. The initial sample for this analysis uses all U.S. tornadoes which occurred since 1970 and have a Fujita scale above 0. This creates a sample size of over 23,000 recorded tornadoes. Total fatalities and injuries as well as the date, time, counties hit, and properties of the tornado such as start and end coordinates, path length, tornado width, and Fujita scale are all recorded by state for each tornado. Annual county-level population data comes from the U.S. Decennial Census and the U.S. Census Bureau's Intercensal Estimates. Data on state-by- decade housing stocks come from the Historical Census of Housing.

Data on NWR transmitters includes their locations, the counties which they cover, and the date on which each transmitter began broadcasting or was permanently deactivated.

Much gratitude is due to NOAA for providing this data. Note that because the database NOAA uses to gather initial broadcast dates was not developed until the 1990's, installation dates prior to that time were gathered by NOAA from old records so some measurement error is possible.

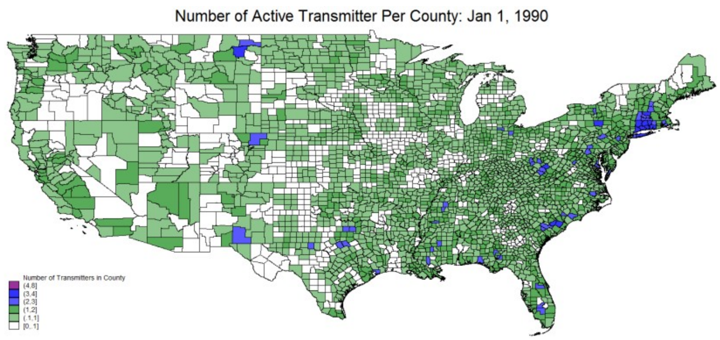

Figure 1: Example of Geo-Spatial Data on Transmitter Coverage

3.2. Methodology

This paper uses two complementary strategies to estimate the causal impact of NWR transmitters on tornado injuries and fatalities. The first is a cross-sectional analysis which examines a broader set of observations but could plausibly have selection bias concerns. The second is an unbalanced panel FE analysis which sacrifices some external validity in exchange for a more robust identification strategy. For each tornado, injuries and fatalities are recorded by state. Both methods use poisson regression analysis to estimate the causal impact of NWR transmitters on tornado injuries and fatalities.

The independent variable of interest is a [0, 1] treatment intensity variable representing the percentage of counties on a tornado's path which receive broadcasts from at least one NWR transmitter. Differences in coverage are due to the tornado location and whether the tornado occurs before or after transmitter begin broadcasting. Because both the location and timing of transmitter installation is non-random, many important controls are included. The identification assumption is that conditional on these controls, transmitter broadcast areas are only correlated with tornado injuries and fatalities through their transmission of warnings.

Controls for the location and timing of transmitter installation can be described under three broad categories. The first category is a vector of tornado properties which accounts for tornadoes with longer paths being mechanically more likely to enter a county with a broadcasting transmitter. It contains a quadratic measure of path length and indicators for the number of counties hit. The second category is a vector of characteristics of the location of the tornado to account for transmitters being more likely to be built in certain areas such as densely populated areas or areas with certain types of housing infrastructure. This vector contains state fixed effects, several controls for population, and decade-by-state measures of the percentage and number of residences of different housing types. Controls also include the area of each of the three largest impacted counties is controlled for to account for correlation between a county's physical area and its probability of having a transmitter. Finally, location-specific controls for the number and size of tornadoes a county has historically received account for areas more prone to tornadoes being more likely to have NWR transmitters. The third category is a vector of variables related to the timing of the tornado to control for changes over time in the probability that tornadoes will be recorded. Year fixed effects control for coverage being higher in later years when fatalities or injuries may have decreased for other reasons. While variables such as the month and time of day a tornado occurs are not obviously correlated with coverage, they are important determinants of outcomes and hence are included to improve model fit.

Even though controls include location and timing information, the analysis of all tornadoes using these controls is at heart cross- sectional with each within-state segment of a tornado as an independent observation rather than a county-level panel. To resolve any concern about unobserved differences between counties, I construct a county-level panel and use panel fixed effects to control for all temporally constant differences between counties. Coverage becomes a binary treatment indicator representing the whether the county was receiving broadcasts from at least one NWR transmitter at the time of the tornado, and only time-varying controls are included.

This panel approach is limited by the fact that fatalities and injuries are measured at the state level rather than the county level. In order to correctly allocate outcomes, this second methodology examines only tornadoes which impacted a single county. This accounts for 91.4% of the tornadoes used in the cross-sectional analysis. Hence these results are driven by a subset of tornadoes with shorter paths. Estimates are driven by counties where treatment is not collinear with county fixed effects. On average these counties receive tornadoes more frequently. For these reasons, the cost of resolving any concern about fixed differences between counties is some external validity.

4. THE VALUE OF NWR TRANSMITTERS & GEO-SPATIAL INFORMATION

It is easiest to first interpret the results from unbalanced panel regression. The estimate is approximately equal to the percent reduction in death and injuries caused by having a NWR transmitter broadcasting over the impacted county. Table 1 reports that having a NWR transmitters broadcasting over a county causally reduces injuries by approximately 38.8%, with a 95% confidence interval of (3.3%, 74.3%). Similarly, having an NWR transmitters broadcasting over a county causally and reduces fatalities by 11.4%, with a 95% confidence interval of (-46.0%, 68.8%).

For the cross-sectional analysis, interpretation is similar. However, 8.6% of tornadoes in the cross-sectional sample impact multiple counties, so coverage measures intensity of treatment rather than a binary treatment indicator. The coefficient on coverage is then approximately equal to the percent reduction in death and injuries caused by having a NWR transmitter(s) broadcasting over all impacted counties relative to none. Table 1 reports that having a NWR transmitter(s) broadcasting over all impacted counties causally reduces injuries by 34.3%, with a 95% confidence interval of (0.2%, 68.4%). Similarly, having an NWR transmitters broadcasting over a county causally reduces fatalities by 50.0%, with a 95% confidence interval of (8.6%, 91.4%).

While these ranges are quite broad, it is clear that NWR transmitters cause a statistically and economically significant reduction in the injuries caused by tornadoes. Current efforts to collect increasingly detailed geo-spatial information regarding transmitter broadcast ranges are expected to help reduce the standard errors by reducing measurement error in transmitter coverage.

Table 1: The Causal Impact of NWR Transmitters on Injuries and Fatalities

	Injuries Cross Section	Injuries Panel	Fatalities Cross Section	Fatalities Panel

% of Counties on Tornado's Path Receiving Transmitter Warnings, "Coverage"	-0.343* (0.174)	-0.388* (0.181)	-0.500* (0.211)	-0.114 (0.293)

Standard errors in parenthesis, clustered at tornado level. * $p < 0.05$. Controls as discussed in Section 3.2.

Another question of interest is whether the benefits of NWR transmitters have remained constant over time. There is some speculation that the rise of substitute warning systems has reduced the benefit of transmitters over time. Figure 1 and Figure 2 provide some insight into this question. The figures present the panel estimates of the causal impact of NWR transmitters on injuries and fatalities, respectively, over a rolling 2-decade window. Standard errors remain quite large, although estimates of the largest causal reduction in deaths and injuries appear in earlier time periods. These figures are complicated by changes in the prevalence of transmitters over time altering which counties are in the comparison groups of treated and control counties.

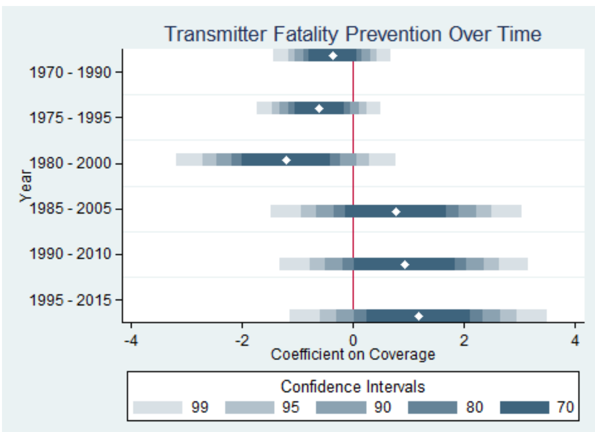

Figure 1: Changes in fatality prevention over time

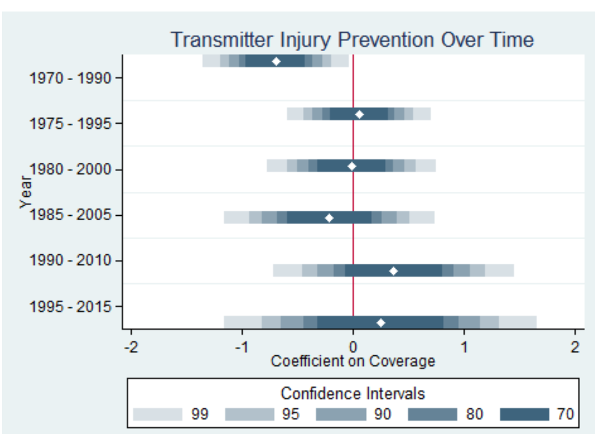

Figure 2: Changes in injury prevention over time

As discussed above, the geo-spatial information employed in this study enables end users such as NOAA and other government organizations to optimally allocate scarce resources within and between government agencies based on the empirical assessments of the performance of systems such as NWR. At the local level, geo-spatial information and the knowledge it enables can helps emergency managers make critical decisions about how to investment and use their weather warning infrastructure.

There are several additional steps which can be taken to further assess the value of geo-spatial information in this setting, and work is underway to fill those gaps. NOAA is currently linking finer-grained geo-spatial data on transmitter coverage areas to population data, which will help reduce the standard errors in these estimates, providing more precise information to end users of results. Additional analysis on the costs as well as the benefits of data collection and system maintenance can offer a more complete cost-benefit analysis

5. CONCLUSIONS

This paper provides the first estimates of the causal impact of a natural disaster warning system on fatalities and injuries. Two different identification strategies find the presence of National Oceanic and Atmospheric Administration's Weather Radio All Hazards (NWR) transmitters causally reduces tornado injuries by almost 40%. Estimates of the causal reduction in fatalities range from 50% to just over 10%. While the 95% confidence intervals are quite broad, it is clear that NWR transmitters play a statistically and economically significant role in public safety. Standard errors remain too large to offer conclusive evidence about whether these benefits have declined over time. Efforts to produce finer-grained geo-spatial data are currently underway.

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Enhancing the uptake of climate change information through participatory approaches for learning in South Africa

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Climate change is projected to increase the frequency and magnitude of extreme weather events of which, without measures to reduce vulnerability, the risk of disasters will also increase and this has the potential to magnify the uneven distribution of risk between the poor and those with wealth (IPCC, 2012; CDKN, 2012). The total cost of weather-related disasters in South Africa was estimated to be approximately R 9.2 billion in the period between 2000 and 2009 (DEA, 2013; DEA, 2015). There is a strong relationship between climate change and development given that climate change will impact on all aspects of society and has the potential to derail social and economic development. Socio-economic development priorities can on the other spectrum be used to mainstream climate change response and ensure the realisation of development goals (IPCC, 2007; AMCEN, 2011). The South African National Planning Commission highlighted the need for improved understanding of the spatial and temporal dimensions to aid spatially equitable and sustainable development outcomes that also take into cognisance the risks posed by a changing climate. At national level, the South African government has committed to minimizing the impacts of climate change and achieving sustainable development. This has been done for example, by signing of the United Nations Framework Convention on Climate Change and the Kyoto Protocol as well as the development of the National Climate Change Policy in 2011.

Although these commitments are made at national level, they depend on lower levels of government and civil society to be realised. The National Climate Change Policy (DEA, 2011:38) also highlights the role of local and provincial governments in responding to climate change. A significant amount of effort has also been put into producing and collating climate change information for use at policy making levels and this includes initiatives by the Department of Science and Technology's through the Global Change Grand Challenge Programme (DST, 2009). The programme seeks to transform South Africa into a knowledge based economy and outputs of this programme include the South African Risk and Vulnerability Atlas (DST, 2011). The objective of the Atlas is to build climate change response capacity of local governments by providing them with information on the vulnerabilities and risks associated with global change including climate change for various sectors. The first phase of SARVA produced the architecture and infrastructure of an online platform, based on an electronic spatial database of risk and vulnerability datasets aimed at providing local government decision makers with climate change information for planning purposes. The second phase focused on among other things the development, population and outreach of the Atlas. From these two phases, the Atlas has connected to a wide range of stakeholders through its thousands of freely available global change data resources, workshops and business breakfasts.

In South Africa local government officials are central in making decisions around spatial planning, land use management and land development at municipal level. This is the same level where the impacts of climate change are usually experienced and as such local authorities are central to addressing these impacts, so that communities can effectively cope and adapt to changes including climate change and variability (Roberts, 2008). This is however, not an easy task as this juxtaposed against other policy goals and social pressures such as the need to meet service delivery backlogs within their urban and rural communities. The vulnerability of rural populations in the country is exacerbated by factors such as dependence on rain-fed agriculture and natural resources to support livelihoods; high prevalence of poverty and marginalisation especially in the former homelands. Post -independence South Africa has seen a significant increase in the number of people moving to and living in urban areas. Reports indicate that currently about 64% of the country's population live in urban areas as compared to 52% in 1990 (SA Government, 2013; World Bank, 2016). As the urban population increased so has the number of peripheral developments; densification and informal settlements (often located in high risk areas) which all pose as a challenge for service provision. Building the resilience of urban areas to the impacts of climate change is critical because this where the majority of the country's population lives and as economic hubs, this is where most built assets and economic activities are located.

Case study: Limpopo Province

The case study of Limpopo has been selected for this research as it one of the provinces that has mix of both rural and urban development and its economy relies heavily of agriculture, tourism and mining that are also vulnerable to changes in climate. Polokwane is one of the major urban hubs in the province is considered to be among the five fastest growing urban centres in the country with a population growth rate of 2.13%. Limpopo as province has developed a Geospatial Analysis Platform (GAP which is a common, meso-scale geo-spatial platform for the assembly, analysis and sharing of economic, development and demand information for the province that can be linked to climate information on SARVA. Tools such as GAP provide representative maps of the country that can help improve strategic development planning, especially at local government level. However the use of climate information through the various tools such as the Limpopo GAP and other spatial tools such as SARVA and SARVA-GAP at local government level has not been effective in most municipalities in the province. In a participatory workshop with stakeholders from the Limpopo province representing the five district municipalities namely, Mopani, Greater Sekhukhune, Waterberg, Capricorn and Vhembe participants identified the following as some of the reasons why local government officials have still failed to use climate information to supplement spatial planning through GAP.

- Poor accessibility and lack of knowledge on the existing data sets of climate information as well as spatial planning tools such as GAP
- There is a lack of GIS technical support at municipal level making it difficult for sector departments to use this spatial data to inform decisions.
- The climate information provided to local governments from SARVA and other science organisations is at national or provincial level and cannot be applied at local level with certainty.
- Management at local government (district and local municipality) level has been unsupportive of climate change projects which are often seen as an unfunded agenda.
- There are instances where government officials who have been trained (train the trainers) to share and apply climate change information at local level are not committed to implementing what they have learnt.
- Products such as SARVA have tended to be conceived and produced in the traditional way of producing knowledge (e.g. Mode 1 Gibbons et.al, 1994) that uses a linear science production model (science transfer to user) rather than the Mode 2 where users are part of the production process.

Research Methodology

This study explores the role that other participatory platforms such as networks and cycles of knowledge sharing can play in connecting the scientists, policy and decisions makers so as to promote social learning. The study recognises that there is need to incorporate experiential knowledge so that it becomes tangible (through reports and other documents) and policy is more reflective of the realities at local level (Patel et.al, 2015). Science based institutions have not fully exploited the opportunity to co-produce and integrate scientific information with tacit knowledge held by local government officials in order to enhance uptake of information. Three workshops with stakeholders from the district municipalities are planned to provide insight on the climate and spatial information user needs, current adaptive capacity to respond climatic risks as well as identifying the challenges and the support required to enhance adaptive capacity. The Appreciative Inquiry (AI) model is being applied in the workshops with stakeholders to answer the following;

- **Definition:** defining climate change risk and impacts in Limpopo
- **Discovery**: What is good and has worked to enhance climate change response in the different districts?
- **Dream:** What structures/mechanisms and resources might be needed for Limpopo to become more resilient to the impacts of climate change and global change?
- **Design: (What should be and what is ideal?)** Based on what has worked in the past and present for a mechanism/structure to assist with climate change response to be useful what should it be able to do? What guidance should it provide and what form should it be in? (Groups work to use assets discovered in the second phase to design a plan to create the desired future)
- **Destiny:** How to make it happen i.e. could current tools (e.g. GAP, SARVA, Lets Respond Toolkit) be improved to cater for the needs of the identified users. What information

could be added to current tools to meet user needs/requirements to improve understanding and use of climate information for planning and decision making?

The definition, discovery and dream stages on the AI model have been completed. In the definition and discovery stages participants worked in the groups representing each district and in the dream stage and subsequent stages discussions will be combined to allow participants to develop a shared vision on how to make their province more resilient to climate change.

Results

The preliminary findings of the analysis indicate that all districts have been affected by climate change, with impacts including flooding of both urban and rural areas, rainfall variability affecting rain fed agriculture and resulting in decreased yields and higher food prices on the local markets. Heatwaves and increased number of very hot days are affecting human health especially agricultural workers. All districts have to some extent embarked on climate change response initiatives that are currently operational and these include drafting of climate change response strategy as well as the identification of climate vulnerability and risks (e.g. in Capricorn& Thulamela). Other initiatives include climate smart agriculture projects with communities, water harvesting and clearing of alien invasive species. However, most of the municipalities do not have completed local climate change policy documents to inform these initiatives.

In the ideal world participants expressed that they need to be involved in the production of knowledge and the development of different outputs to meet different stakeholder groups. Participants also indicated the need for knowledge sharing platforms through networks and forums including improved access to information on the research done by universities in the province; financial resources to implement climate change projects; and commitment by politicians and other officials. This study continues to explore the role of participatory approaches in enhancing climate change adaptation at local government level through a series of workshops that are being used in this case study to promote co-learning and co-production of knowledge on the climate change risks in Limpopo. Municipalities will continue to need support to reduce emissions and build equitable and resilient spaces.

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Using ocean color satellite data to estimate economics benefits associated with monitoring and preventing harmful algal blooms

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ABSTRACT: This presentation describes proposed work that will use satellite data to detect and monitor harmful algal blooms (HABs) in freshwater lakes to support two types of economic analyses. In the first part of the analysis, we will identify the extent to which information from remote monitoring of HABS can act as a substitute for using traditional field-based monitoring programs. These cost savings can be used in any number of ways to improve programs aimed at minimizing the occurrence of HAB events. In the second component of the analysis, we will use data derived from satellite imagery to characterize the frequency, duration, and spatial extent of HAB events across freshwater lakes. The information will then be used to construct realistic scenarios describing the state of HAB events in a particular region or set of waterbodies. The realistic scenarios will form the baseline scenario in a stated preference study to estimate the economic benefits associated with avoiding HAB events. This project is a joint effort between four U.S. agencies (EPA, NASA, NOAA, and USGS).

***Keywords*: economic valuation, harmful algal blooms, ocean color satellites**

1. INTRODUCTION

Across the U.S. many states are developing programs to monitor harmful algal bloom (HAB) events (Graham et al. 2009). However, monitoring costs money, it takes time, and results are often not available in a time-frame that is relevant to some management decisions. Automated detection and forecasting of events based on remote sensing has the potential to improve the quality and timing of HAB related data delivered to resource managers and the public. Automated monitoring may also lead to substantial costs savings. This cost savings would provide flexibility to reallocate scarce public resources into programs focused on reducing the causes of bloom events.

Despite the importance of improving monitoring programs for bloom events in freshwater lakes, there is scarce information on how public resources are being spent on this problem and little is known on how the public values efforts to reduce water quality hazards such as harmful algal blooms. To address the paucity of research in this important area, we plan to implement two distinct threads of research.

First, we will begin by exploring the issue of assessing the economic value of information derived from the satellite data. There are many dimensions to this question. Remote sensing data has many uses and users of the information will derive different kinds of benefits. Ultimately, the economic value of this information depends on how individuals, organizations, or governments choose to use the information and how those choices are transformed into outcomes that matter to people. In terms of HABS, these outcomes may range from improving environmental quality to protecting public health and safety.

The initial approach taken here focuses on the specific issue of identifying how harmful algal blooms are currently detected and monitored (using traditional field-based programs) and estimating the economic costs associated with those programs. With an understanding of how these programs operate, we will then attempt to identify the extent to which information from remote monitoring of HABS can act as a substitute for particular components of these programs. With this information, we will be able to develop a rough estimate of the avoidance costs derived from using remote sensing data.

The second thread of economic research will examine the economic benefits associated with avoiding HAB events using stated preference methods. While this part of the research will not explicitly derive an economic value of using the satellite data, the stated preference choice experiment will heavily rely on the remote sensing data to construct scientifically valid baseline scenarios (sometime referred to as the status quo conditions) that underpin the choice experiment. By using remote sensing data to accurately construct and describe baseline conditions related to HAB frequency, spatial extent, and duration, the hope is that one can minimize many of the problems associated with using hypothetical baseline conditions.

1.1. Overview of the CyAN Project: A Multi-Agency Project to Monitor HABS with Satellite Data

This project is an effort between four federal agencies (EPA, NASA, NOAA, and USGS) to develop a new approach for mainstreaming satellite ocean color capabilities into U.S. water quality management decisions. This project is also on the forefront of U.S. government research on sustainability, as recommended by the National Research Council's report "Sustainability for the Nation", supporting interdisciplinary research focused on connections among environmental, economic, and social problems (NRC, 2013). Despite ecosystem, economic, and public health concerns, toxins from cyanobacteria are infrequently assessed due to the cost, required expertise, and time necessary for proper analysis. Measuring and monitoring water quality parameters is time and cost intensive, often requiring a field team to spend a majority of the day on a boat sampling a single waterbody.

Toxic cyanobacterial blooms have been documented across the U.S. and many states have issued health advisories or closed recreational areas due to the potential risks from exposure. In 2014, the city of Toledo, Ohio was required to issue a "Do Not Drink" advisory for residents served by the municipal water system. States have experienced many challenges in the development of monitoring programs for HABs. There are difficulties in developing appropriate sampling plans that address large number of waterbodies while faced with limited financial resources and affordable detection methods.

The CyAN project will develop capability to detect and quantify algal blooms using satellite data records. Studies on cyanobacteria have included evaluation of a variety of satellites including Landsat, ocean color monitor (OCM), MODIS, and MERIS. Satellite instruments with the smallest spatial footprints (<300m) provide the best opportunity for monitoring HAB events. Satellite capabilities that will support the development of CyAN data products include: MERIS, MODIS-Aqua/MODIS- Terra, OLI, Sentinel-2A/2B and OLCI. The project will evaluate data derived from all of these satellites to develop a consistent national standard and strategy for detecting and monitoring HAB events in as many waterbodies as possible.

While satellite data is accessible to scientists, it is often not processed and delivered to public or other users in a manner that is practical for many management decisions. The CyAN project will also work to develop an information dissemination system for expedient use by stakeholders of freshwater systems.

2. CHARACTERIZING HOW REMOTE SENSING DATA CAN BE USED TO SAVE ON MONITORING COSTS

This part of the project will focus on the specific issue of identifying how harmful algal blooms are currently detected and monitored (using traditional field-based programs) and estimating the economic costs associated with these strategies. We will then use the satellite data to determine how many waterbodies and the total spatial coverage (i.e. area) that can be monitored for each state using state-of-the-art detection algorithms developed within this project. The temporal frequency of monitoring (both field-based, and satellite monitoring) will also be taken into consideration. All of this information will then be combined to determine the potential cost savings (or avoided costs) that will be available to states as a result of using the remote sensing data. There are two distinct components to these savings. First, there are the cost savings associated with using the remote sensing data to monitor waterbodies in lieu of on-going, more traditional field-based monitoring programs. Secondly there is a hypothetical savings associated with the ability to monitor waterbodies that were not previously monitored under current programs.

To be more concrete, suppose that a given state has a program specifically designed to detect and monitor HAB events in a limited set of waterbodies. Tasks associated with the program might include the following:

Activity	Costs
Field monitoring plan development	16 hours
Checking / ordering equipment	20 hours
Collecting field data (travel time and time spend to monitor ten sites, five times per year).	1040 hours
Analysing data to generate useful water quality measures similar to those obtained vis-à-vis remote sensing.	80 hours
Total	1156 hours

After obtaining the workflow for particular monitoring programs, it will then be necessary to identify how the data products from the CyAN project can act as substitutes for these activities. This will be accomplished by speaking with water quality monitoring experts.

In addition to examining how the CyAN data products could save on costs associated with field monitoring, we will also attempt to identify the extent to which existing HAB monitoring programs could be expanded by virtue of the fact that it should be possible to detect and monitor HAB events on many more waterbodies using the remote sensing data products than is currently possible using traditional field programs. For each of the states in this analysis, we will determine how many waterbodies and how much total area can be monitored using the remotely sensed data and the HAB detection algorithms. We will also attempt to determine the temporal frequency of measurements that can be obtained from the CyAN products. This may vary depending on characteristics of the specific set of satellites used and to some extent the weather patterns in a particular region. For example, in some states that experience frequent cloud-cover during the summer months, it may be not be feasible to obtain satellite readings during particular satellite flyovers.

3. USING REMOTE SENSING DATA TO IMPROVE ESTIMATING THE ECONOMIC VALUE OF AVOIDING HAB EVENTS

The second thread of economic research will examine the economic benefits associated with avoiding harmful bloom events using stated preference methods. The stated preference choice experiment will use the CyAN project data products to characterize baseline scenarios that better reflect actual, 'status quo' conditions than a set of hypothetical baseline conditions. Because the benefits of water quality improvements are generally not valued in markets, measuring the economic value of water quality improvements associated with reductions in HAB bloom events requires a nonmarket valuation approach. The satellite data will be used to characterize the frequency, duration, and spatial extent of HAB events and this characterization will be used to describe scientifically valid baseline scenarios that act as a reference point that reflects the state of HAB events in a particular region or set of waterbodies. This baseline characterization will act as the starting point for estimating the economic benefits associated with alternative management options designed to prevent HAB events. The use of a scientifically valid estimate of baseline conditions is important for a number of reasons.

An important finding in the behavioral and experimental economics literature is reference dependence. Reference dependence relates to the idea that individuals use the status quo or baseline as utility reference point and they judge losses and gains relative to this point (Whittington and Adamowicz, 2011). In addition, many stated preference studies have shown the presence of status quo bias, which essentially means that respondents participating in the choice experiment assign greater utility to the status quo option that can be explained by the attributes of the given choices. The implication of conducting a study with hypothetical – rather than real – baseline conditions in the presence of reference dependence or status quo bias is that the result of the valuation exercise may have less policy relevance and the estimation results may be less reliable. Essentially, hypothetical bias in valuation estimates is more likely to be minimized when survey respondents are presented with a single hypothetical scenario to consider (i.e. the alternative choice options relative to the status quo) than when they are asked to evaluate a double hypothetical in which both the status quo baseline and alternative choices are hypothetical. By minimizing hypothetical bias (leading to stronger validity of the valuation results) and using a baseline scenario grounded in reality, our goal is to generate an estimate of the economic benefits that arise from preventing or avoiding harmful algal blooms. The satellite data will play an essential role in developing realistic baseline scenarios that underpin the choice exercises. We also plan to include in our survey instrument a set of contingent behavioral questions that will be used to better understand behavioral responses to HAB warnings and events. Using a set of realistic baseline scenarios to guide these questions will hopefully elicit more realistic and accurate information from respondents just as it should for respondents answering contingent valuation questions.

The actual economic value of using the satellite data to develop baseline scenarios, will be difficult to value in terms of dollars. For this particular use of the data, the benefit is 'progress in science', or an improvement in a social science methodology. This kind of benefit is much more difficult to 'value' in money-metric terms. This latter point illustrates the challenges underlying the general concept of placing economic value on geospatial data or information. Ultimately that value depends on how the information is used. Because geospatial information has so many uses, it is a large challenge to estimate the complete set of benefits that may be generated from its use. The geospatial data products characterizing HAB events in the CyAN projects could potentially be used to evaluate and improve policies that attempt to improve water quality along a number of dimensions. Use of the geospatial information could be used to assess and prioritize waterbodies suffering from HAB events, it could be used to evaluate the progress of policy programs designed to avoid HAB events, and it could also be used to design economic studies to evaluate the benefits of reducing HAB events as is the case in this study. All of these uses of the data generate economic value or benefits but each of the end-uses may require a different study and methodology to evaluate the benefits. Not unlike some ecosystem services such as water quality, geospatial information can simultaneously act as a 'final good' with direct utility to its users, but it may also act as an 'intermediary good' that is used as an input to produce another good that is directly valued by end- users.

4. MEASURING THE VALUE OF GEOSPATIAL INFORMATION AND CONCLUSIONS

As noted above, this abstract describes planned research. The value of geospatial information is complex and is highly dependent on the context for which the information is used. The CyAN project will develop methods and tools for detecting, quantifying and distributing information about HAB events using satellite data. It would be ideal to have capacity to evaluate and estimate all of the benefits that can be derived from using this information. This project will start more modestly. First we will evaluate the extent to which the satellite-derived information on HAB events can act as a substitute for traditional field-monitoring efforts.

This will allow us to estimate the avoided costs associated with adopting this new information resource. Second, we will use the CyAN data characterizing the spatial extent, frequency, and duration of HAB events to develop realistic baseline scenarios in a stated preference experiment designed to estimate economics benefits associated with avoiding or reducing HAB events. Using realistic baseline scenarios should increase the validity of the valuation estimates and increase their relevance for policy decisions. These are two very different uses of the data, but both have real economic values.

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A method to estimate societal benefit derived from Earth observations: An example from the United States' National Earth Observation Assessment

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The United States invests in civil Earth observations to deliver benefit to society. It does this through the development, operation, and maintenance of a portfolio of Earth observing systems, networks, and surveys that measure critical parameters of the Earth system; the programs that analyze the resulting data and develop and disseminate information products; and lifecycle data management activities. To characterize the contribution of Earth observations to a range of societal benefit areas (SBA), the second Earth Observation Assessment (EOA 2016) is being conducted through the U.S. Group on Earth Observations (USGEO) Subcommittee of the interagency National Science and Technology Council's Committee on Environment, Natural Resources, and Sustainability.

EOA 2016 follows a value tree analysis approach to evaluate the current portfolio of Earth-observing systems (EOSs) according to their relative impact within 13 thematic SBAs. The value tree connects EOSs to the SBAs to which they contribute. Teams of Federal subject matter experts (SMEs) define elements at each level of the value tree. The elements within each SBA include thematic sub-areas, and, under each sub-area, a set of key objectives (KOs) that help deliver benefit to society through the contribution of current Earth observations. Under each key objective, SMEs list the key products, services, and outcomes (KPSOs) that are currently used to accomplish the KOs. The bottom of the value tree consists of the intermediate information products and Earth observation inputs that contribute to the development of each KPSO.

To assess the relative impact of an Earth observation system within and across SBAs, it is necessary to assign weights at each level of the value tree. These weights allow the relative impact of a given system on a KPSO to be scaled by the weight of the KPSO to the key objective, the weight of the KO within the sub-area, the weight of the sub-area within the SBA, and finally, the weight of the SBA, which is 1/13th of the total weight of all of the SBAs.

In order to weight the KOs and the sub-areas, it was necessary to design a method that (1) results in weights that reflect the relative contribution of EOS to achieving societal benefits, (2) can be repeated consistently with each of the SBA teams, and (3) is easy for the SBA team members to carry out. To help the SMEs estimate the relative weights of the different KOs, we used an elicitation method based on the Simple Multi-attribute Rating Technique Exploiting Ranks (SMARTER) system.[1] SBA team members were presented with the following prompt: "Earth observations are critical for realizing many societal benefits. In the value tree for your SBA, the key objectives reflect the various ways Earth observations currently contribute to societal benefits." The team members were asked to vote for the top 50% of KOs in an SBA that, in their view, currently provide the most societal benefit from Earth observations. The votes from each team

[1] Ward Edwards and F. Hutton Barron, "SMARTS and SMARTER: Improved Simple Methods for Multiattribute Utility Measurement," *Organizational Behavior and Human Decision Processes,* **60**, 306-325 (1994).

member were summed to calculate the total number of votes for each KO. KOs were then ranked across all sub-areas and within each sub-area. The rank ordered centroid (ROC) model was used to convert the ranks into weights. For an SBA with K key objectives, the weight of the kth key objective, w_k, across all sub-areas was calculated as follows:

$$w_k = \left(\frac{1}{K}\right) \sum_{i=1}^{K} \left(\frac{1}{k_i}\right)$$

The initial weights of KOs across all sub-areas were used to develop initial sub-area weights, and initial weights of key objectives within a sub-area were used to develop initial KO weights. SMEs then participated in a guided discussion to determine the final weights by consensus.

Of the 13 SBAs, 11 have gone through the weighting process to-date. The value trees structures for each of the SBAs differ: they have between 3 and 5 sub-areas and between 11 and 40 total key objectives, with each sub-area having between 1 and 13 key objectives. To evaluate the extent to which SBA teams preserve the originally calculated key objective rankings, the Spearman's rank correlation coefficient was calculated between the initial and final ranked list of KOs. The Spearman's rho values for the individual SBAs range from 0.55 to 0.97 ($p<0.05$), with an overall value of 0.90 ($p<0.01$) across all SBAs weighted to-date, suggesting a high degree of correlation between the initial ranking of key objectives and the final ranks within and across all SBAs. Initial evaluation shows that the sub-areas that contain higher numbers of KOs experience smaller changes between the initial and final KO weights than sub- areas containing fewer KOs.

The method developed for EOA 2016 allows SMEs to assign weights to key objectives and sub-areas based on the provision of societal benefit using Earth observations rather than their agency priorities. In addition, using all team members' votes to develop initial weights prevents anchoring to an equal distribution of weight among value tree elements or to a single team member's perspectives.

Understanding and Assessing the Value of Improved Satellite Data for the Users of Operational Sea Ice Products and Information

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ABSTRACT: The importance of attributing socioeconomic benefits of the data collected by meteorological satellites – the value derived from the practical application the data and data products - is increasingly important to the Coordination Group for Meteorological Satellites (CGMS) members as they seek to defend public investments in existing and planned meteorological satellite programs. As a current priority, CGMS Socioeconomic Benefits Tiger Team (SETT) has initiated a pilot socioeconomic benefit study: *Understanding and Assessing the Value of Improved Satellite Data for the Users of Operational Sea Ice Products and Information.*

***Keywords*: CGMS, SETT, meteorological satellites, sea ice.**

1. INTRODUCTION

The Coordination Group on Meteorological Satellites (CGMS) Socioeconomic Benefits Tiger Team (SETT) was established in response to increasing pressure on CGMS members to better justify public investments in space-based Earth observation systems. The SETT's primary goal is to provide guidance to CGMS members by identifying credible methodologies and common terminology for conducting and/or contracting out socioeconomic benefit (SEB) studies. The purpose of this presentation is to acquaint the audience with how the CGMS SETT serves as an example of a community of practice to improve the capacity of its members to undertake SEB analyses.

The CGMS provides an international forum for the exchange of technical information on geostationary and polar orbiting meteorological satellite systems. CGMS's goals are to coordinate and support operational weather monitoring, forecasting, and climate monitoring in response to requirements specified by national and international agencies including the World Meteorological Organization (WMO), a specialized agency of the United Nations (UN).

In 2013, the CGMS established the Socioeconomic Benefits Tiger Team (SETT) to identify credible methodologies and common terminology for articulating the socioeconomic benefits of satellite observing systems, and to explore the most effective ways to communicate the benefits to decision makers and stakeholders. To accomplish these goals, the SETT recruited expertise from across the CGMS membership, including from its academic partners, and compiled members' experiences and ideas on how to evaluate the usefulness of meteorological data. The Tiger team has participants from the U.S. National Oceanic and Atmospheric Administration (NOAA) and NASA in the United States, EUMETSAT and the WMO, as well as the Canadian Space Agency and the Chinese, Japanese, and Korean Meteorological Satellite Agencies.

2. SETT PILOT SOCIOECONOMIC BENEFIT STUDY

In 2015, SETT members agreed to undertake a pilot SEB study, *Understanding and Assessing the Value of Improved Satellite Data for the Users of Operational Sea Ice Products and Information,* to serve as an example for CGMS Members considering sponsoring their socioeconomic benefit studies on their own satellite programs or applications. The principle purpose of the pilot study is to provide an important community learning opportunity on the process and steps to carry out an analysis of the value chain from observations through modelling/analysis, sea ice products, end user decisions, and outcomes, to the end stage of societal value. The SETT sought to identify a pilot study relevant to multiple CGMS members and manageable in scope. In addition, the SETT looked for SEB study that would yield process lessons that would be generalizable to other studies of interest to CGMS members.

Understanding and Assessing the Value of Improved Satellite Data for the Users of Operational Sea Ice Products and Information was chosen for its relevance and manageable scope. Ship operators in the Arctic depend on timely, accurate, and relevant information about sea ice extent and thickness in the navigable waters of the Arctic. Governments of the Arctic region (U.S., Canada, Denmark, Russia, Finland, Norway, Iceland, and Sweden) have an operational responsibility to provide updates of sea ice conditions to vessels navigating in the Arctic. Sea ice analyses and forecasts are primarily prepared using satellite imagery and ice reconnaissance. The remoteness of the Polar Regions limits the amount of direct observation of sea ice.

According to the U.S. National Ice Center more than 95% of the data used in sea ice analyses are derived from the remote sensors on polar-orbiting satellites. The sea ice and iceberg products and information provided by national and international ice services (e.g. The North American Ice Service, U.S. National Ice Center, Canadian Ice Service, etc.) enable safe and efficient maritime operations.

SETT members agreed that they would contribute in-kind technical expertise regarding the relative contributions of satellite instruments and data to operational sea ice products to support this study, noting the need to seek outside economic expertise for the conduct of the study itself.

MEASURING VALUE OF GEO-SPATIAL INFORMATION

Information on the highly variable sea ice conditions (especially thickness and extent) is important for safe and efficient operations in the Arctic. This pilot study will seek to evaluate the role of remote sensed data in the development of the sea ice products used in marine operations (e.g. marine transportation, commercial fishing, recreational cruises, search and rescue, and other key sectors) to reduce risk, improve response, and enhance efficient operations.

The SETT SEB study will seek to:

- Evaluate improvements to sea ice forecasting products and information resulting from new sources of satellite data and information, e.g. Sentinel Series Synthetic Aperture Radar (SAR) and Suomi National Polar-orbiting Partnership (S- NPP Visible Infrared Imaging Radiometer Suite (VIIRS);
- Assess and characterize how sea ice products are used by operators in the Arctic to make decisions and how outcomes change as a result;
- Quantify the socioeconomic benefits of remote sensing observations on the sea ice products and information used by operators in the Arctic; and
- Identify the qualitative benefits (e.g. national/international policy drivers) that could influence investment in advanced remote sensing to improve operational sea ice products (e.g. Arctic Council priorities).

The analysis will build upon data collected as part of the CGMS SETT's efforts, as well as a range of previous publications on related matters (i.e. value of improved meteorological satellites, estimates on impacts of shipping, etc.). Parallel assignments by CGMS SETT members to assess the impact of satellite data on sea ice forecasting products and services, contributing to project design, will also help inform the analysis. The analysis will use data from the CGMS Members and the Organization for Economic Cooperation and Development (OECD), which are relatively data rich.

3. CONCLUSIONS

The SETT has finalized a Socioeconomic Benefit Study Concept Note and is currently identifying the resources available for completion of the pilot study. The Concept Note assumes CGMS members will contribute in kind and financial resources. Funding contributions to hire a consulting economist to help identify the most appropriate methodology for the study with respect to objectives and data availability.

While the study is designed to inform the meteorological satellite community's efforts to advance and improve socioeconomic benefit analyses of earth observing satellites, the approaches developed and lessons learned in the SETT pilot study are expected to be transferable to other geospatial information areas.

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Spatial Information for Disaster Planning and the Reinsurance Industry

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Spatial information has the potential to improve the ability of government and industry actors, within both developing and developed countries, to understand what population and associated economic assets are exposed to natural and technological hazards and to assist in planning mitigation measures, including seeking insurance coverage. Well-mapped exposure and vulnerability data are necessary to the assessment of risk by development agencies, local and national governments, and risk insurers and managers. Such risk information can provide justification for incorporating disaster resilience in development project planning, such as constructing new infrastructure and retrofitting or renovating existing facilities. Spatially disaggregated risk data can help target revisions to building codes and inspections to assess compliance at the facility level. Supply chain managers can utilize spatial risk data to assess the potential for loss of access or delayed arrival of critical components or key raw materials due to disruption of source areas or transportation networks by different hazards. Commercial enterprises can use this information to underscore the importance of disaster risk preparedness and planning in their own operations and those of suppliers.

Manufacturing facilities, the service economy, and infrastructure investments have grown rapidly in Asia, Latin America, and sub-Saharan Africa, but the development of spatial data and information on critical infrastructure facilities and economic activities in urban and peri-urban areas have not generally kept pace. Reinsurance companies require information on sector-specific areas of exposure at regional and sub-urban scales to adequately assess risk and aid in setting rates. They seek to avoid underwriting a retail insurance company's portfolios of assets that may be exposed to a single major hazard, such as a concentration of property in an area of high earthquake or flooding risk. Rapid assessment of exposure is possible with readily available remote sensing imagery and publicly available aerial and street-level photography in urban areas. Future economic and demographic scenarios from the community contributing to the Intergovernmental Panel on Climate Change (IPCC) assessment process can also be used to characterize future trends in exposure and potential variability in space and time.

We provide a number of examples of business sector and population exposure mapping, including the fusion of remote sensing derived classifications and demographic and economic censuses, critical infrastructure mapping, and application of downscaled future demographic and economic scenarios. These examples are taken from past and ongoing projects involving both public and private sector stakeholders.

Assessing carbon sequestration potential as an ecosystem service for publicly managed lands in the United States

Zhiliang Zhu, U.S. Geological Survey

Carbon sequestration is an ecosystem service because the process stores carbon in its pools for a long term and help mitigate the negative effects of climate change.

Approximately one third of the United States lands and waters are managed as public lands. These lands are national parks, forests, grasslands, and wetlands. Among the many ecosystem services provided by public lands, such as recreation and clean water, is ecosystem carbon sequestration. A recent study by the U.S. Geological Survey (USGS) shows that public lands represented 23% and 82% of the ecosystem carbon sink in the conterminous 48 states and the state of Alaska respectively. The carbon stored in various pools is a long-term ecosystem service. For example, using the USGS study results including Landsat remote sensing of land use and land cover (LULC) change, the amount of carbon stored in national parks in the conterminous U.S. provides a total societal value estimated at 583 million dollars per year (Richardson and others 2015). Applications of remote sensing methods with field observations and processes, as well as simulation models are useful tools for such studies at the national as well as landscape scales. At the landscape scale, different and more of a variety of remote sensing platforms and methods such as LIDAR tend to be used to derive targeted biophysical variables. Below I illustrate the applications of geospatial data products to derive societal benefits in the United States by discussing two separate but related studies we have conducted in evaluating ecosystem carbon sequestration as a societal benefit.

1. A NATIONAL ECOSYSTEM CARBON SEQUESTRATION ASSESSMENT

The USGS has completed a national assessment of carbon stock and sequestration potential of various ecosystems such as forests, agriculture, wetlands, grasslands, and water bodies (see Zhu and others, 2010). The assessment focused on current and future potential carbon balances in relation to key driving forces primarily land use change, land management, climate change and wildland fire. As discussed in Zhu and others 2010, the assessment relied on a methodology to produce nationally consistent and spatially and temporally explicit results. The methodology is illustrated in figure 1.

Several geospatial data products served as the foundation of the assessment, for example, remotely sensed (using Landsat) and interpolated annual land use and land cover maps (Figure 2), national wildfire occurrence and severity data product (Figure 3) derived from Landsat, ecosystem net primary production (NPP, Figure 4) derived from the MODIS satellite, and national soil databases.

From these geospatial data, and also using many other data products such as field inventory data and stream gage data, we ran processed-based and empirically-derived computer models to estimate the current and future LULC change, current and future wildfire, and the current and future distributions of ecosystem carbon stocks (including aboveground biomass, surface debris, belowground biomass, and soils), different flux terms (such as wildfire emissions, lateral flux of dissolved carbon dioxide through rivers and streams), and the net ecosystem carbon balance (NECB). Because our input data and methods were both spatially and temporally explicit, the derived results were annual maps. From these annual maps, we could overlay ownership and management polygons to allow for analysis of societal benefits of a positive NECB (that is, carbon sequestration). We calculated NECB values of all national parks in the United States, and converted the values to societal values of the ecosystem service using the social cost of carbon approach at a 3% discount rate.

Results of the study show that the national parks are a strong carbon sink, sequestrating more than 14.8 million metric tons of carbon dioxide annually. The associated societal value of this service is estimated at approximately $582.5 million per year. Leading parks providing the societal benefits include Great Smoky Mountains and Yellowstone national parks (Richardson and others 2014). Overall, public lands managed by the federal government contributes to 23.3% of the overall ecosystem service (Figure 5). However, the contribution could be reduced to 20.8% by 2050 without any policy intervention (Tan and others 2015).

Because the results are annualized, and because annual funding levels supporting the input data products are generally known, it is possible to estimate, on an annual basis, the direct contribution of the funding support that lead to the societal benefit of carbon sequestration to the general public.

2. SCIENCE SUPPORT FOR THE GREAT DISMAL SWAMP RESTORATION

The Great Dismal Swamp (GDS), located in the coastal plain of the mid-Atlantic region of the United States, is a publicly managed national wildlife refuge and contains a unique carbon-rich peatland ecosystem called pocosin, which is home to many wildlife and migratory bird species including black bears and red-cockaded woodpecker. Over the more than 200 years, the swamp has experienced a variety of land use changes, including building of ditches that started when George Washington owned the land. The ditches are believed to have drained the wetland and led to change in vegetation composition as well as hydrology regime, which have been vital in maintaining the healthy characteristics of the peatland. In recent years, there have been several catastrophic wildfires, emitting large quantity of organic carbon and destroying the habitat.

Like many other public parks and wildlife refuges, the managers are more preoccupied with a host of management objectives such as bird viewing and providing of clean water to citizens. However, to restore the ecosystem to its healthy state includes actions to manage soil wetness, return the wildfire frequency to its historical regime, and change the species composition. These actions would restore peat thickness, wetness, and chemical characteristics, which is consistent to protecting and increasing carbon sequestration (Figure 6).

To provide the science in support of the GDS management goals, the USGS is conducting a study, which covers several topics to meet the needs of the managers and other stakeholders. As shown in Figure 9, the topics include measurement of aboveground biomass, soil carbon density, estimation of wildfire emissions, surface GHG emissions, surface and ground water hydrology, elevation change relevant to sea level rise, and modeling of ecosystem services. So far, the wildfire emission task has been completed and other work tasks are ongoing. We discuss below briefly the results and progress.

To quantify GHG emissions of a recent fire (Lateral Fire of 2011, Figure 10), the USGS scientists used before- and after-fire LIDAR data (Figure 7) combined with field measurements. By deriving relative difference of before- and after-fire elevation and quantifying uncertainties of LIDAR data point distribution, it was possible to estimate the loss of carbon from the peatland soil and aboveground biomass pools. On average, the results show that the elevation change due to the fire was 0.46 meters, and the fire was responsible for emission to the atmosphere of 1.1 million metric tons of carbon, or 44.3 kilograms of carbon per square meter (Reddy and others 2015). The results are worth noting because the emissions on the unit-area basis were significantly higher than those of Indonesia or Alaska peat fires. The authors also noted that the use of LIDAR data was instrumental in providing a confident estimate of the loss of peat carbon.

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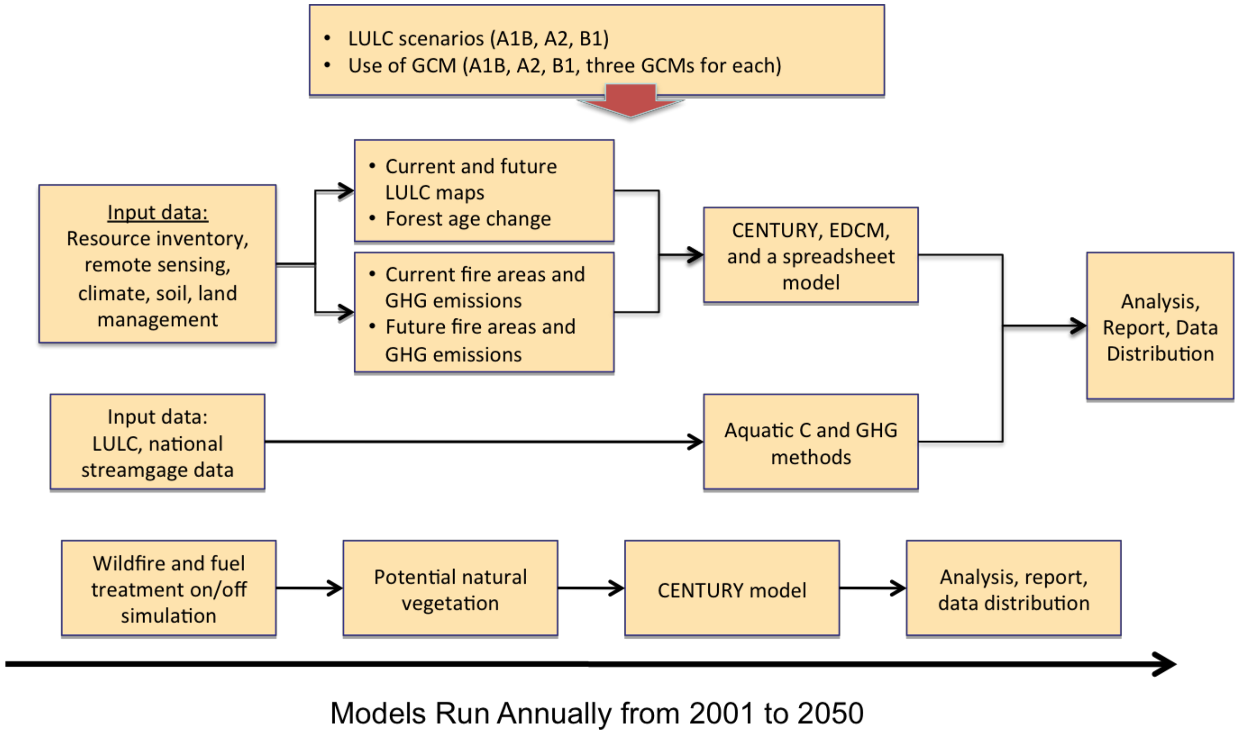

Figure 1. Flowchart of the methodology used for the recently completed USGS carbon sequestration assessment for the United States.

Figure 2. Landsat-derived land use and land cover map of the conterminous United States as of 2011.

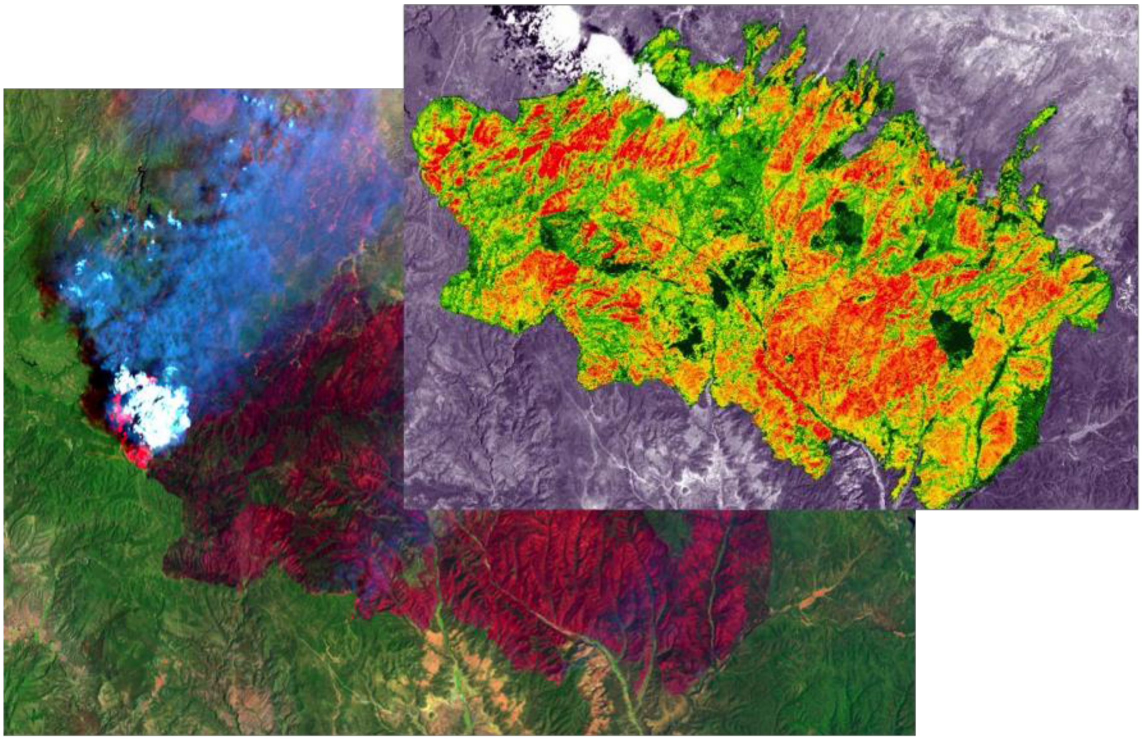

Figure 3. Landsat imagery (bottom) and estimated severity of burn of the 2002 Arizona Rodeo Fire. Geospatial data such as this are used in estimating fire-induced greenhouse emissions.

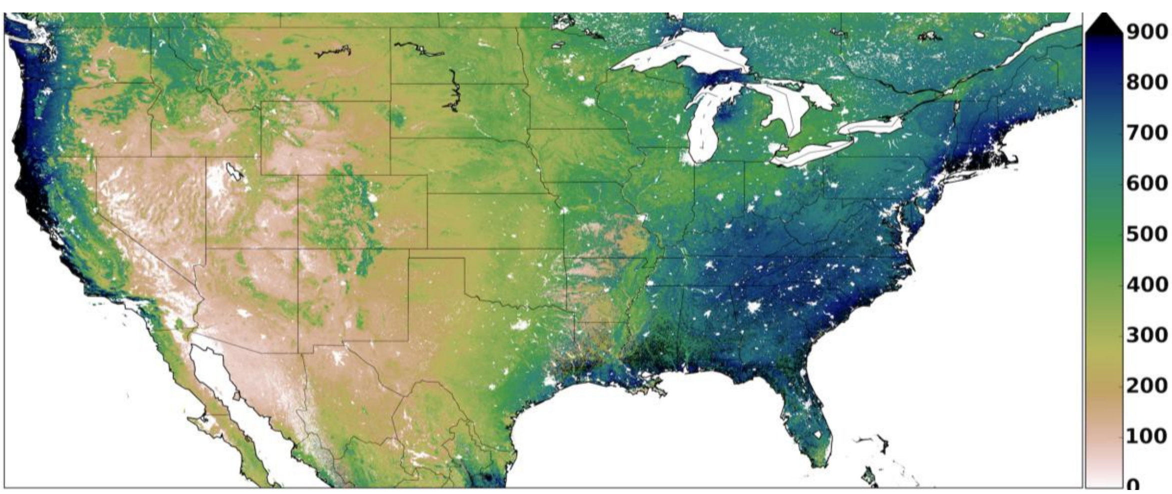

Figure 4. Average annual net primary productivity between 2000 and 2014 derived from the MODIS sensor.

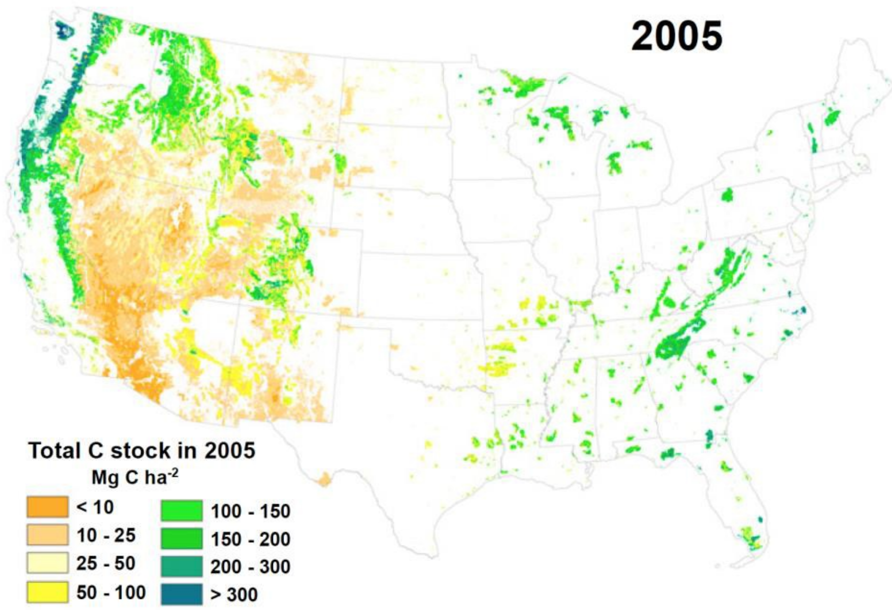

Figure 5. Distribution of ecosystem carbon stock of federally managed lands in 2005.

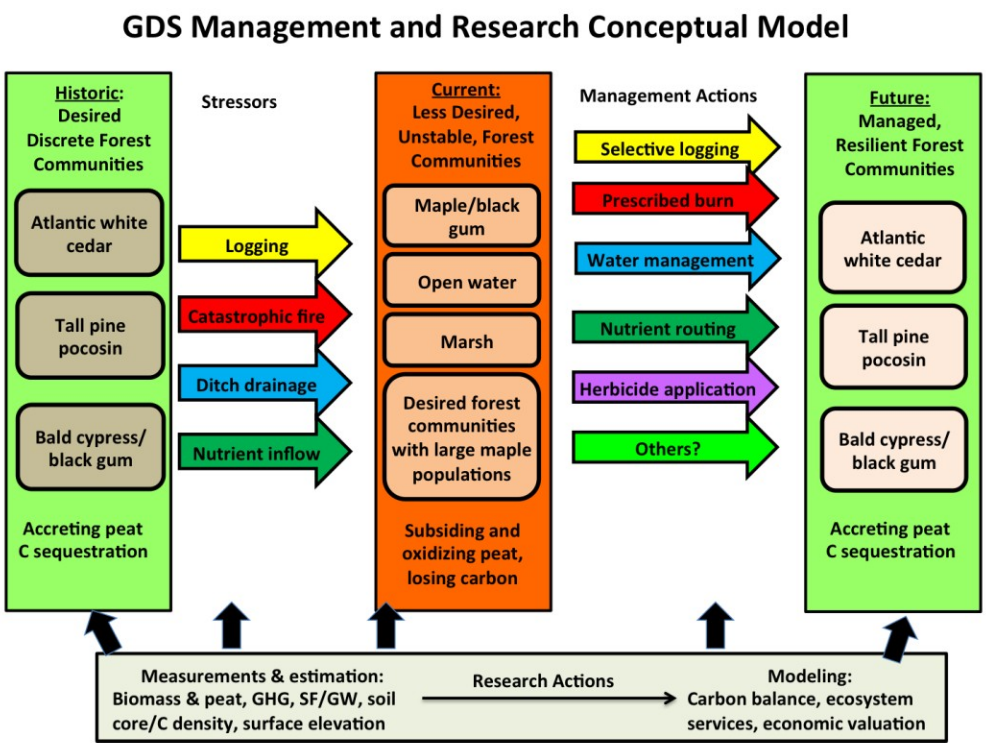

Figure 6. A conceptual model used for guiding research at the Great Dismal Swamp (GDS) to produce science information to help support public land management to restore ecosystem conditions.

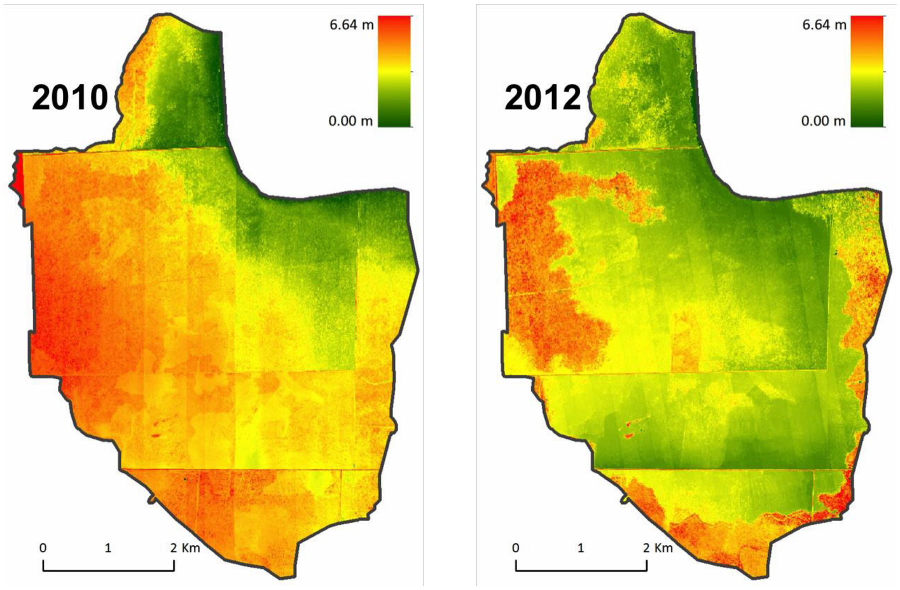

Figure 7. LIDAR acquisitions obtained in 2010 and 2012, before and after the 2011 Lateral Fire in Great Dismal Swamp.

E-poster Display Summaries

Sytze de Bruin, Associate Professor, Geographical Information Science Wageningen University, Laboratory of GIS and Remote Sensing, Netherlands

Dr. de Bruin is interested in uncertainty analysis to assess fitness-for-purpose, data acquisition, including spatial and temporal sampling and sensing, spatio-temporal interpolation, and quantitative methods used in spatial and temporal analysis. He has been involved in research projects with applications ranging from land degradation assessment to precision agriculture. He worked four years in Central America (Costa Rica and Nicaragua) as an applied soil scientist. His research and education focus on using sound methodology for transforming spatial data into useful geo-information. He has written over 45 papers published in peer-reviewed international journals, is associate editor of the International Journal of Geographical Information Science, and serves on the editorial board of Spatial Statistics.

"Fitness-for-Use of Geospatial Information Products: Uncertainty and Value"

Sytze de Bruin, Wageningen University
Arnold Bregt, Wageningen University
Martin Herold, Wageningen University
Rose Maria Roman Cuesta, Wageningen University
Nandin-Erdene Tsendbazar, Wageningen University

Spatial data quality has been a topic of research for several decades but the usefulness of spatial data quality parameters needs to be improved to enable valuation of geospatial information in real-world applications. In this paper, we list a variety of studies focusing on methodological aspects of fitness-for-purpose assessments as well as case studies in this research field. Relevant methods involve error modelling accounting for spatial correlation of map errors, propagation of input uncertainties through models, and the expected value of information (EVOI) for ex-ante assessment of the value of geospatial information products. We finish by underscoring the need for comprehensive and convincing studies on valuation of geospatial information for complex socioeconomic decision making.

Robert Downs, Senior Digital Archivist and Acting Head of Cyberinfrastructure, Center for International Earth Science Information Network (CIESIN), the Earth Institute, Columbia University.

"Spatial Information for Disaster Planning and the Reinsurance Industry"

Dr. Robert R. Downs is Vice-Chair of the Columbia University Morningside Institutional Review Board and holds the PhD in Information Management from the Stevens Institute of Technology. He is a member of the Board of Directors of the Foundation for Earth Science Information Partners (ESIP) and is a member of the Editorial Board of the CODATA Data Science Journal. He is a Senior Member of the Association for Computing Machinery (ACM) and is a member of the American Geophysical Union (AGU), the Association for Information Science and Technology (ASIS&T), and the International Association for Social Sciences Information Services and Technology (IASSIST).

Nikolay Khabarov, Research Scholar, International Institute for Applied Systems Analysis (IIASA), Ecosystems Services and Management Program (ESM)

Dr. Khabarov has been a principal investigator and contributor to a range of IIASA's research projects with a particular focus on benefits of improved Earth observations; crop growth modeling; economics of adaptation; assessment of disasters, climate change impacts, and adaptation options; estimation of the value of information; and modeling of carbon market and regulatory risks and their reduction through innovative financial tools. His expertise is mathematical modeling and optimization under uncertainty with a rich set of applications including natural disasters (e.g. forest fires and related GHG emissions) and risk-optimal portfolios (e.g. technological portfolios for power generation. He has been involved in more than 15 international research projects.

"Valuing Weather Observation Systems for Forest Fire Management"

Nikolay Khabarov, International Institute for Applied System Analysis
Elena Moltchanova, University of Canterbury
Michael Obersteiner, International Institute for Applied System Analysis

Weather information is an integral part of modern fire management systems. In this paper, we investigate, by means of modeling, how improvements in the weather observation systems help to reduce burned area by targeting and monitoring places ripe fires are likely to occur. In our model, air patrolling is used for fire detection. The patrolling schedule is determined by the Nesterov fire danger index, which is calculated from observed weather data. We use two weather data sets based on "rough" and "fine" grids. The reduction of the total burned area, associated with an air patrolling schedule based on the "fine" grid, indicates the benefits of using better weather observations. We explore the sensitivity of the model with respect to the quality of input data and find the largest marginal improvement from the rough grid results when observation is refined in most critical areas.

John Leslie King, Bishop Professor of Information, University of Michigan

John Leslie King is former Dean of the School of Information and former Vice Provost at the University of Michigan. He came to Michigan in 2000 after twenty years on the faculty of the University of California at Irvine. He has published widely on the relationship between changes in information technology and changes in organizations, institutions, and markets. He has been a senior editor of many journals, a member of the Computing Research Association (CRA) Board and the Council of the Computing Community Consortium, and on numerous National Science Foundation advisory committees and National Research Council studies. He is a Fellow of the Association for Information Systems and a Fellow of the American Association for the Advancement of Science.

"Stakeholder Alignment Collaborative; Challenges to Societal Value from Geospatial Information"

Getting value from geospatial information requires sharing. A study of over 2,000 respondents from the EarthCube initiative shows that people like the idea of sharing, but challenges remain. These include ineffective markets due to traditions of monopsony and monopoly. The presentation concludes with what is required for success and pragmatic suggestions for speeding up the process of change.

Yusuke Muraki, Engineer, Japan Aerospace Exploration Agency (JAXA).

"Policy and Earth Observation Innovation Cycle (PEOIC) project"

Yusuke Kuwayama's research focuses on the economics of water resource and ecosystem management. After working in the International Space Station (ISS) program at JAXA for seven years, he is now seconded to Asian Development Bank (ADB), a regional development bank to support developing countries in Asia and the Pacific to achieve poverty reduction and economic growth. He has a leading role in introducing satellite applications to the new field of sustainable development of developing countries, as the first and only staff in charge of space technology. His recent work addresses groundwater use in the agricultural sector, the water resource impacts of oil and gas development, the societal value of hydrologic information, and the economics of wastewater treatment.

Michael Papenfus, U.S. EPA, Office of Research & Development

Michael Papenfus' research approach to the protecting the environment is informed by the integration of ideas from economics, microeconomics, ecology, and natural resource management so that all of these contribute to improving decisions that people make. His work focuses on estimating the value of environmental and resource services so that this information can be valuable part of the information and knowledge base that support environmental and resource management decisions and policy. He is currently working on valuation projects using both revealed and stated preference methods to value a wide range of ecological services including water quality, wild fish populations, and demand for outdoor recreation. He is also beginning to explore connections between environmental quality and human health outcomes.

"Using Ocean Color Satellite Data to Estimate Economics Benefits Associated with Monitoring and Preventing Harmful Algal Blooms"

This presentation describes proposed work that will use satellite data to detect and monitor harmful algal blooms (HABs) in freshwater lakes to support two types of economic analyses. In the first part of the analysis, we will identify the extent to which information from remote monitoring of HABS can act as a substitute for using traditional field-based monitoring programs. These cost savings can be used in any number of ways to improve programs aimed at minimizing the occurrence of HAB events. In the second component of the analysis, we will use data derived from satellite imagery to characterize the frequency, duration, and spatial extent of HAB events across freshwater lakes. The information will then be used to construct realistic scenarios describing the state of HAB events in a particular region or set of waterbodies. The realistic scenarios will form the baseline scenario in a stated preference study to estimate the economic benefits associated with avoiding HAB events. This project is a joint effort between four U.S. agencies (EPA, NASA, NOAA, and USGS).

Lucia Lovison-Golob, Afriterra Foundation, Boston.

Lucia Lovison-Golob is AIP-GEOSS Capacity-Building Leader for GEOSS-AIP disaster management and risk reduction projects in Latin America (particularly in Chile), Africa, and Asia. She is Geospatial Director and Librarian, cataloguing metadata, and geospatial developer. She was project Director and Librarian for a project related to cartography and geography for the One Laptop per Child (OLPC), now available to schools around the world. She is also a member of the Digital Technologies in Cartographic Heritage Working Group of the International Cartographic Association (ICA-ACI) and served as Co-chair of the Open Data Access and Intellectual Property Rights for Cartography Working Group, International Cartographic Association.

"Data to Decisions: Valuing the Societal Benefit of Geospatial Information in case of Disasters such as Earthquakes and Tsunamis"

The issue of how to convert data to information and then to decision is applied it to Chilean application tool. Within the Architecture Implementation Pilot (AIP) project, Capacity Building Working Group (CB WG) that I'm coordinating, we have selected seven test pilot areas related to earthquakes, tsunamis, volcanic eruptions and fires. We are applying a service oriented architecture (SOA) that allows each agency (national of international) to manage its own data silos; however each agency agrees to make the metadata of those data available through web services according to a GEO Common Infrastructure (GCI) platform that is interoperable according to OGC (Open Geospatial Consortium) and ISO (International Standard Organization) geospatial standards. We look to capture the geographic diversity and increase Chile's resilience to disasters by developing a model for evaluating the socio-economic impact of web services, in order to allow emergency personnel, regional authorities and others, to optimize their decisions in relation to the characteristics of the disasters. In this paper, I plan to consider initially earthquakes and tsunamis to promote feedback and possible collaboration between the communities stricken by a disasters and the decision makers.

Appendix 1: Workshop participants

Name		Organization
Aldo	Aldama	Permanent delegation of Mexico to OECD
Lesley	Arnold	Curtin University, Perth, Australia
Yazidhi	Bamutaze	Makere University, Uganda
Karl	Benedict	University of New Mexico, USA
Jared	Berenter	The Palladium group
Rich	Bernknopf	University of New Mexico, USA
Gordon	Campbell	European Space Agency
Andrew	Coote	Consulting Where, UK
Joep	Crompvoets	KU Leuven, Belgium
Sytze	De Bruin	Wageningen University, Netherlands
Vincent	Dedieu	French Ministry of Defense
Robert	Downs	Columbia University, USA
Vanessa	Escobar	NASA, USA
Lawrence	Friedl	NASA, USA
Johanna	Frojdenlind	Lantmäteriet National Land Survey of Sweden
Jason	Gallo	Mission Applications Coordinator
Anita	Gibson	OECD
Pierre	Glynn	USGS, USA
Johnathan	Gourley	NOAA, USA
Dillon	Green	US mission to UNESCO
Roswitha	Gruemann	DLR, Germany
Dominique	Guellec	OECD
Balan Alejandro	Gutiérrez Herrera	Agencia Espacial Mexicana (The Mexican Space Agency), Mexico
Elisabeth	Haeggquist	Lulea University of Technology, Sweden
Ivan	Hasic	OECD
Leon	Hauser	Space technology institute, Hanoi, Vietnam
Einar-Arne	Herland	Norwegian Space Center, Norway

Name		Organization
Jacob	Hochard	East Carolina University, USA
Claire	Jolly	OECD
Donna	Kain	East Carolina University, USA
Aleski	Kalenius	Permanent delegation of Finland to OECD
Melissa	Kenney	University of Maryland, USA
Nikolay	Khabarov	IAASA, Austria
Suzette	Kimball	USGS, USA
John Leslie	King	University of Michigan, USA
Calvin	Klatt	Natural Resources, Canada
Jamie	Kruse	East Carolina University, USA
Yusuke	Kuwayama	Resources for the Future, USA
Muriel	Lafaye	CNES National Centre for Space Studies, France
Jeff	Lazo	National Center for Atmospheric Research, USA
William	Lecky	UK Space Agency, UK
Steven	Lev	IDA, USA
Lucia	Lovinson-Golob	Afriterra Foundation
Molly	Macauley	Resources for the Future, USA
Paida	Mangara	SANSA, South Africa
Tanaka	Masafumi	French Ministry of Economy, Industry and Digital Affairs, France
Robert	Mendelsohn	Yale, USA
Laure	Ménétrier	French Ministry of Economy, Industry and Digital Affairs
Benjamin	Miller	Rand, USA
Stuart	Miller	Terragotech, Perth, Scotland
Douglas	Muchoney	USGS, USA
Yusauke	Muraki	Japan Aerospace Exploration Agency
Miriam	Murambadoro	CSIR, South Africa
Mattia	Olivari	OECD
Michael	Papenfus	Environmental Protection Agency, USA
Jung Ho	Park	Korea Aerospace Research Institute

Name		Organization
Francoise	Pearlman	J&F Enterprises, USA
Jay	Pearlman	J&F Enterprises, USA
Mark	Pelling	King's College, UK
Gilles	Ragain	CNES, National Centre for Space Studies, France
Barbara	Richardson	UK Space Agency
Giovanni	Rum	GEO, Switzerland
Barbara	Ryan	GEO, Switzerland
Carl	Shapiro	USGS, USA
Alan	Smart	ACIL Allen Consulting, Australia
Fanglin	Sun	University of California at San Diego, USA
Anna	Svedlund	Lantmäteriet National Land Survey of Sweden
Emily	Sylak-Glassman	IDA, USA
Alicja	Tamiz Christiansen	Agency for Data Supply and Efficiency, Denmark
Jurkka	Tuokko	National Land Survey Finland
Marit	Undseth	OECD
Glenn	Vancauwenberghe	KU Leuven, Belgium
Danny	Vandenbroucke	KU Leuven, Belgium
Ingrid	Verstaeten	USGS, USA
Stéphanie	Willekens	European Space Agency
Charles	Wooldridge	NOAA, USA
Andrew	Wyckoff	OECD
Zhiliang	Zhu	USGS, USA

Workshop organizers

Francoise Pearlman, Manager, J&F Enterprise, Community Outreach and Coordination.

Francoise Pearlman has 30 years of experience in engineering and management including system of systems engineering, software engineering and software/system integration and testing. For over 15 years, she has applied her management expertise to government programs with focus on development, integration, and field testing of digitization software/systems. Francoise has also participated in numerous technical reviews and proposals for a wide range of information systems and Command and Control programs. After a career in technical management for major aerospace corporations, she is currently co-owner of J&F Enterprise, a small technical services company operating in the global dimension. She is a senior member of IEEE.

Jay Pearlman, J & F Enterprise, University of Colorado

Dr. Pearlman has 40 years of experience in science, development, and systems activities. His background includes basic research, program management, and program development in systems, sensors, information technology, and the impacts of information on decision-making. Dr. Pearlman is technical director of J&F Enterprise and Professor (adjunct) at the University of Colorado. Jay focuses on research and applications in oceans and large-scale information systems. He is co-chair of the NSF EarthCube Technology and Architecture Committee and a member of the U.S. Committee for the Research Data Alliance, both addressing data interoperability on a national and international scale. Dr. Pearlman also continues his efforts in Earth observation and geospatial information.

Jamie Kruse, Director, Center for Natural Hazards Research; Distinguished Professor of Economics, East Carolina University; Senior Scientist, Institute for Coastal Science and Policy

Dr. Kruse is recognized for her research in economics and decision making under uncertainty especially as it relates to natural hazards. She completed her doctoral work at University of Arizona under dissertation advisor, Vernon Smith (2002 Nobel Laureate). Dr. Kruse has published over sixty refereed journal articles in addition to proceedings, abstracts, and reports. She has held faculty positions at the University of Colorado, Texas Tech University, East Carolina University, and a visiting position at Eidgenossische Technische Hochschule (ETH) in Zurich, Switzerland. Her work has been supported by National Aeronautics and Space Administration, National Science Foundation, U.S. Geological Survey, Department of Energy, National Institute of Standards and Technology, Federal Emergency Management Agency, Department of Homeland Security, Federal Deposit Insurance Corporation, Niagara Mohawk, State of Texas and the State of North Carolina. In 2010, she held the position of Chief Economist at National Oceanic and Atmospheric Administration.

Lawrence Friedl, Director, Applied Sciences Program, Earth Science Division, NASA. Washington, D.C.

Lawrence Friedl leads efforts to discover and demonstrate innovative and practical applications of Earth science by public and private organizations. He has been with the NASA Applied Sciences Program since 2002. Among his responsibilities, Lawrence is a Co-Chair of the interagency U.S. Group on Earth Observations (USGEO) and represents the United States on the international Group on Earth Observations (GEO). He is the NASA Principal for the interagency Civil Applications Committee. He also serves on the Award Committee for the National Space Club's Award for Innovative Uses of Earth Observation Satellite Data, the Program Organizing Committee for the American Meteorological Society 2014 meeting, and the International Committee for Remote Sensing of Environment.

Carl Shapiro, Director of the USGS Science and Decisions Center; Senior Economist, Energy & Minerals, and Environmental Health, USGS Survey Science & Decisions Center, Reston, VA.

SDC provides an interdisciplinary focus to enhance the use and value of scientific information emphasizing research and application in five science areas: (1) ecosystem services; (2) decision science; (3) resilience; (4) participatory science and innovation; and (5) natural resource economics. Before his work with SDC, Carl spent almost 20 years as the Principal Economist in the USGS Office of the Director, where he initiated, led, and participated in multidisciplinary studies. While in the Director's Office, Carl also served as Senior Advisor to the Director and Acting Chief, Office of Strategic Planning and Analysis. Carl has received the Department of the Interior's Meritorious Service and Superior Service Awards. Carl is an adjunct associate professor of economics in the School of Public Affairs at American University in Washington, DC, where he has taught graduate courses in economics and public management.

Claire Jolly, Head, OECD Space Forum/Ocean Economy Group, Directorate for Science, Technology, and Innovation; Organization for Economic Co-operation and Development

Claire Jolly is a Senior Policy Analyst and Head of Unit in the Directorate for Science, Technology, and Innovation. In the Organisation for Economic Co-operation and Development (OECD). She heads the OECD Space Forum and the Ocean Economy Group. She joined the OECD in 2003, after providing policy and economic analysis to public and private organizations in aerospace and defense in Europe and North America. Her background is in international economics (Univ. Versailles and Cornell University) and aerospace engineering (ENSTA, Paris).