Chapter 4

Benefits Assessment of Applied Earth Science

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4.1 Introduction

Fresh water, air quality, deforestation, food security, urbanization, sanitation, land management, disease, biodiversity, hygiene, economic growth, and disasters. These and many others are all global challenges with environmental and resource dimensions. Increasingly, people and organizations are using Earth observations and scientific information about the Earth to gain insights on and inform their policy and management decisions related to these challenges.

Along with numerous organizations globally, NASA has been a key contributor to the wealth of data and information about the Earth and its processes. In addition, NASA has helped advance global knowledge about effective ways to apply the data and information across sectors and thematic areas. There are countless examples on how organizations have and are using Earth observations to support specific analyses, decisions, and associated actions.

Many of these examples have been qualitative and anecdotal. The substantiation of Earth observation benefits in societal and economic terms poses key challenges, yet this quantitative substantiation is of strategic importance to the Earth observation community as it expands efforts to inform decisions. It is at the heart of the value proposition. In addition, it comes at a time when there are increasing efforts to encourage greater integration of the social and economic sciences with natural sciences as well as global efforts to use data and indicators to address sustainability.

This chapter describes NASA's work to enable uses and applications of Earth observations, as well as efforts to quantify the socioeconomic impact and showcase the overall value of space-based observations.

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4.2 Earth Science and Applications

One of NASA's agency-wide goals is to "advance understanding of Earth and develop technologies to improve the quality of life on our home planet" (NASA 2014). NASA's Earth Science Program supports fundamental and applied research on the Earth system, discovering new insights about the planet and the complex interactions within the Earth system.

Using the vantage point from space, global perspectives enable NASA to provide a broad, integrated set of high-quality data covering all parts of the planet. NASA shares this unique information openly with the global community, including members of the science, government, industry, education, and policy-maker communities (NASA 2014).

Within NASA Earth Science, its Applied Sciences Program is a dedicated effort to promote innovative and practical uses of Earth observations. The Program supports applied research and applications projects to enable near-term uses of Earth observations that inform organizations' decisions and that build key capabilities in the Earth science community and broader global workforce. Projects are carried out in partnership with private and public-sector organizations to achieve sustained uses and benefits from Earth observations. The Program addresses technical and human barriers to the use of new data and tools, creating new knowledge about effective methods and processes for applying Earth science (e.g., Hossain 2014).

4.3 Inform Decisions

Within the scientific community, the identification of the human role in and impacts on the Earth system have grown significantly. There are clear human dimensions to physical and biological parameters, such as air quality conditions and land use patterns.

With this recognition have come numerous efforts supporting greater integration of natural and social sciences. A U.S. National Academy of Sciences report suggested efforts "to facilitate crosscutting research focused on understanding the interaction among the climate, human, and environmental systems ..." (NRC 2009). The Future Earth initiative stemmed from the proposal for "a new contract between science and society in recognition that science must inform policy to make more wise and timely decisions ..." (ICSU 2012). In the U.S., the Obama Administration directed U.S. Federal agencies in 2015 to factor the value of ecosystem services into Federal planning and decision-making (OMB 2015). The U.S. Global Change Research Program's (USGCRP) 2012 Strategic Plan also included an objective on greater integration with social, behavioral, and economic sciences (USGCRP 2012).

This integration also offers significant opportunities to improve decision-making. Knowledge from the decision sciences, economics, and other social sciences can support ways to better incorporate Earth observations into analyses used for policy and business management decisions. Notably, the USGCRP's Strategic Plan introduced a goal focused on informing decisions for the first time in the USGCRP's history. The language of policy and business management is often an economics-based lexicon. The integration will require adjustments within the natural science and Earth observation communities (Mooney 2013). However, the integration can help the Earth observation community gain skills to articulate its value and improve its support to decision-making.

It is with these trends that NASA has supported significant efforts to quantify the socioeconomic benefits of Earth observation applications and build familiarity within the Earth observation community.

4.4 Socioeconomic Benefits of Earth Observations

As suggested, national and international organizations are placing greater emphasis on the benefits achievable from applications of Earth observations. The determination of specific societal and economic impacts, especially quantitatively, can be challenging, yet these determinations are critical to the value proposition of Earth observations and to induce greater use.

NASA Earth Science and its Applied Sciences Program have supported numerous studies to assess and document the benefits of Earth observations for decision-making. NASA has and continues to advance analytic techniques and quantitative methodologies for determining socioeconomic impacts across a range of themes.

Some of the socioeconomic studies that the Applied Sciences Program has sponsored include

- Disasters: Volcanic ash and aviation safety;
- Water: Improving water quality management;
- Health: Malaria early warning using Earth observations;
- Drought: Value of information for the U.S. Drought Monitor;
- Ecosystems: Fisheries management and pelagic habitats;
- Air Quality: Enhancements to the BlueSky emissions assessment system;
- Wildfires: Benefits of BlueSky for smoke management and air quality; and,
- Air Quality: Earth observations and the Environmental Protection Agency's (EPA) AIRNow system.

The following are summaries of two project-impact studies that the Applied Sciences Program has sponsored; the information is paraphrased from the authors' reports and also appeared on the program's website.

4.4.1 Earth Observations and Air Quality

Air pollutants can cause significant short-term- and long-term effects to human health. The U.S. EPA operates the AIRNow air quality system, which health officials use to alert the public about hazardous pollution.

A NASA-sponsored project pursued the use of Aura, Aqua, and Terra data within the EPA AIRNow air quality system. By incorporating the Earth observations into AIRNow, EPA could expand the system's coverage to reach millions of people not currently covered by the network of ground-based air quality monitors.

In the project's economic impact report, the analysis involved two approaches: face-to-face interviews in three case study locations (Denver, Colorado; Atlanta, Georgia; and Kansas City, Missouri) to assess the public value or community-level benefits and analysis of cost savings from the use of satellite data instead of installing new monitors to provide air quality information for public health decisions to populations in currently unmonitored locations.

The study found that the addition of satellite data could provide daily particulate matter information to 82% of people living in currently unmonitored locations (approximately 15 million people); the study estimated that the capability represents a value of about USD 26 million.

The three case studies also identified nonmonetary value and benefits. Interviewees reported reduced adverse health impacts on sensitive populations resulting from more accurate air pollution warnings and health alerts, and increased public viewing and understanding of air quality maps on AIRNow because of greatly increased spatial coverage. They also reported increased media use of AIRNow air quality maps resulting from expanded geographic coverage; more comprehensive air quality stories available to the media because of improved geographical representation of pollutant transport resulting from unusual events; and better communication with the public about the spatial distribution of air pollution, especially in sparsely monitored areas, resulting in better public understanding of these issues.

4.4.2 Volcanic Ash, Earth Observations, and Aviation Safety

Large volcanic eruptions can eject ash to heights at which commercial aircraft normally fly. Volcanic ash can cause damage to engines and fuselages, making it necessary to reroute, delay, or cancel flights to protect aircraft and ensure passenger safety. The international aviation community uses information and warnings from nine Volcanic Ash Advisory Centers (VAAC) on the location of volcanic ash.

In 2010, Iceland's Eyjafjallajökull volcano erupted, sending volcanic ash into European airspace and canceling flights. European VAACs had not used Aura data, and a NASA-sponsored project team developed and delivered data products within

days of the eruption. European officials used the Aura products in their determinations of which airspace to open.

An impact analysis analyzed the benefits of the project and VAAC's use of Aura data. One part focused on the benefits from use following the Eyjafjallajökull eruption, and one part focused on a global estimate of average annual benefits.

The analysis team used data on flight cancelations and revenue losses due to Eyjafjallajökull, historical frequencies of aircraft damage from volcanic ash, and aircraft repair costs. The team estimated how much the Aura data would reduce the uncertainty about the level of ash threat, determining a risk-adjusted value of the observations. Overall, the analysis found that the satellite data reduced the probability of an aircraft experiencing a volcanic ash incident by approximately 12%.

The team estimated that use of the data following the Eyjafjallajökull eruption saved USD 25–72 million in avoided revenue losses due to unnecessary delays and avoided aircraft damage costs. If the data had been used from the beginning of the incident, an estimated additional USD 132 million in losses and costs might have been avoided.

The team extrapolated the risk-adjusted results globally to estimate the potential annual impact from the use of Earth observations by VAACs. Accounting for annual frequency and magnitude of volcanic eruptions, the team estimated an expected value of up to USD 10 million annually.

4.5 Sustainable Development Goals

These efforts to measure the impacts of Earth observations on decision-making mirrors and aligns with other endeavors globally to use data to advance social, economic, and environmental progress. Most notable are the United Nations' Sustainable Development Goals.

In 2015, the United Nations endorsed Transforming Our World: the 2030 Agenda for Sustainable Development, a global development agenda for all countries and stakeholders to use as a blueprint for progress on sustainability. The 2030 Agenda specifically calls for new data acquisition and exploitation of a wide range of data sources to support implementation, including a specific reference to Earth observations and geospatial information.

Thus, the 2030 Agenda represents a key opportunity for Earth observations to play insightful roles in monitoring targets, planning, and tracking progress that can contribute toward achieving the goals. The long-term collection of data on the goals provides worldwide opportunities to produce examples and further develop analytic methods on the socioeconomic benefits of Earth observations.

4.6 Conclusion

Earth observations are often one of many sources of information that are used in decision-making activities. The articulation of the specific impact from Earth observations on a decision can be challenging to substantiate fully, yet the pursuit has both intellectual and strategic benefits. Similarly, a familiarity with the terms and methods of the social and economic sciences provide the Earth observation community with greater opportunities and audiences.

The global community has made significant strides in the past decade to begin tapping satellite data for the purposes of policy and management decisions. Thus, further efforts to determine and document Earth observations' impacts in socially and economically meaningful terms can support broader efforts to employ the data, seek additional data, and lead to additional advances and further societal benefits.

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Author Biography

Lawrence Friedl serves as the director of the Applied Sciences Program within the Earth Science Division at NASA Headquarters. The program supports efforts to discover and demonstrate innovative and practical applications of Earth science by government, business, and other organizations. He has been with NASA since 2002 and he has served as the program manager for air quality applications along with several other applications themes. Among his responsibilities, Lawrence is a vice-chair of the interagency U.S. Group on Earth Observations (USGEO) and is the NASA principal for the interagency Civil Applications Committee. He represents the United States in the Group on Earth Observations (GEO), serving as a co-lead on a GEO initiative on sustainable development goals (SDGs). He chairs the International Committee for Remote Sensing of Environment and serves on the National Space Club's Award Committee for Innovative Uses of Earth Observation Satellite Data.

Prior to joining NASA, Lawrence worked at the U.S. Environmental Protection Agency (EPA), focusing on applications of geospatial data and technology. He also served as a space shuttle flight controller in NASA's Mission Control Center for 15 missions, including several Earth science missions. He joined the U.S. federal government as a presidential management intern. Lawrence received a master's degree in public policy from Harvard University's Kennedy School of Government, specializing in science and technology policy. He received a bachelor's degree in mechanical and aerospace engineering from Princeton University. He also received a certificate in space policy and law from the International Space University.

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