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USING EARTH OBSERVATION DATA TO HELP ACHIEVE THE UNITED NATIONS SUSTAINABLE DEVELOPMENT GOALS

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In September 2015, more than 150 world leaders met at the United Nations Sustainable Development Summit to adopt the 2030 Agenda for Sustainable Development which included an ambitious set of goals improve encourage economic growth, improve social inclusion and advance environmental protection. Building on the successes of the original 8 Millennium Development Goals, the 17 Sustainable Development Goals (SDGs) officially came into force on 1 January 2016. They include provisions on: poverty, hunger, health, gender equality, clean water and sanitation, energy, livelihood and economic growth, industry and infrastructure, inequality, cities and communities, responsible consumption and production, climate action, sustainable water resources, sustainable land resources, governance and justice, and global partnerships. Each goal has specific, integrated targets and indicators to ensure measurable, transparent progress by 2030. Though the SDGs are not legally binding, all countries agreed to build out national frameworks for achievement of the goals including monitoring progress. However, the goals are not meant to be achieved by state action alone and will require the commitment of many international actors working in a variety of innovative ways. Geospatial technologies (GIS, GPS, remote sensing) are a cost-effective way of collecting information about large, relatively unpopulated or difficult to access areas and have already been integrated successfully in many programs on agriculture, water, land use planning, disaster management, and climate change. This paper will explore how Earth observation technology can be used to address some of challenges faced in achieving the SDGs, with a particular focus on less-traditional areas such as poverty reduction, small-scale infrastructure, health, human rights, and governance. It will examine implemented and proposed case studies and analyze barriers to expanding the use of Earth observation data.

I. INTRODUCTION

On September 18, 2000, at one of the largest gatherings of world leaders in history, 189 countries adopted the United Nations Millennium Declaration, affirming their commitment to solving economic, social, cultural or humanitarian problems in developing countries and economies in transition. By setting specific targets to be met by 2015, they hoped to ensure that globalization was a positive force for everyone. These targets became known as the Millennium Development Goals (MDGs) and were instrumental in spurring action and focusing attention on how extreme poverty could be addressed. Focused on decreasing extreme poverty in the poorest countries, the MDGs sought to address many dimensions of poverty including income, hunger, maternal health, child mortality, disease, gender equality, education, and environment.

The living conditions of many around the world have improved since 2000. The number of people living in extreme poverty has fallen from 37 percent since 1990 with most of the progress occurring post-2000 [1]. The net enrollment rate for primary school in the developing regions rose from 83 percent in 2000 to 91 percent in 2015. [2] The number of new HIV infections decreased from an estimated 3.5 million cases in 200 to 2.1 million in 2013. [3] Child mortality rates have fallen and access to clean water has improved. [4] However, despite these gains, not all of the goals were met, particularly in sub-Saharan Africa. When they expired, the United Nations pushed to build on the overall success of the MDGs by creating a new 15-year plan.

Thus in September 2015, more than 150 world leaders met at the United Nations Sustainable Development Summit to adopt the 2030 Agenda for Sustainable Development which included new goals focused on an expanded effort to create a better future for the entire world. The 17 new targets, known as the Sustainable Development Goals (SDGs), officially came into force on January 1, 2016. The SDGs are even more ambitious than the MDGs and include provisions on: poverty, hunger, health, gender equality, clean water and sanitation, energy, livelihood and economic growth, industry and infrastructure, inequality, cities and communities, responsible consumption and production, climate action, sustainable water resources, sustainable land resources, governance and justice, and global partnerships. They are more broadly written to highlight the needs of all countries rather than just focusing on the developing world. By their very designation, they also include a much stronger focus on sustainability, the idea of development efforts that meet the ongoing needs of the present and the future. Each goal has specific, integrated targets and indicators to ensure measurable, transparent progress by 2030.

Another core feature of the SDGs is their focus on how to implement, including the need for strong partnerships, mobilization of financial resources, improved capacity-building efforts, and the importance of technology and data. Though the SDGs are not legally binding, all signatories agreed to build out national frameworks for their achievement and for monitoring progress. Yet, the goals are not meant to be achieved by state action alone and will require the commitment of many international actors working in a variety of innovative ways.

Encouraged by the establishment of the new SDGs, people across many sectors, regions, and backgrounds are evaluating how to contribute. Projects within the field of international development, which overseas projects based on official and private development funding, are particularly important for understanding how the goals will be meet. Further, it's acknowledged that one key to success will be the leveraging of science tools. This paper examines how one category of technology, Earth observation and its related data, can provide value to projects in support of the SDGs.

II. EARTH OBSERVATION

Earth observation together with geospatial technologies can provide unique benefits to projects supporting the SDGs in a diversity of ways. Earth observation satellites, by recording data on large sections of the Earth, provide an important source of information for anyone carrying out development projects. Taken together with geospatial technologies, they will be crucial for finding solutions to the SDGs. Geospatial technologies commonly denote a variety of tools, such as remote sensing, geographic information systems (GIS), and Global Positioning System (GPS), that are used for measuring, visualizing, and analyzing Earth's features. This paper will focus on space-based remote sensing, which is when the sensors on board a satellite collect data by detecting the energy reflected from Earth. Combining remote sensing data with other location-specific information is often known as geospatial data. The result is the capacity for mapping and analysis of geocoded information.

Satellite images can provide a unique way to assess a particular situation or event on the ground. By showing a series of images over a period of time, they can help reconstruct a sequence of events. High resolution images can be used for investigating highly targeted phenomena with a narrow field of vision during a specific timeframe. Low resolution imagery is better at depicting regional phenomena that may require more systematic and repetitive collection.

While satellite imagery has been used by the defense industry for decades and by many commercial sectors for years, the changing landscape of technology provides an important driver for increasing its use. The growth of the commercials space industry, in which many new companies were established with helping the world as part of their mission, the proliferation in small satellites and other cost-decreasing technologies, and improvements in data analytics are all factors. The proliferation of no- or low-cost images along with free and open source software for managing the data has allowed more industries to explore ways of integrating the use of Earth observation data.

Remotely sensed data can safely provide information about locations that are too difficult or dangerous to access directly or where it's essential to integrate location human-related data points—a common situation for international development projects. In addition, satellite imagery can help address some of the challenges faced in developing nations with large, relatively unpopulated areas. Being able to observe these areas, thereby reducing the need for and enhancing ongoing data collection on the ground, can be more cost-effective and allows new avenues of programming with better results tracking. Further, observation and analysis can be done in a non-intrusive, objective and repeatable manner providing for more fair and equitable decision-making.

Thus, Geospatial data has much to offer anyone seeking to advance the SDGs, a fact acknowledged in the text of the 2030 Agenda. In paragraph 76, signatories agreed to "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." [5]

Commonly or prominently cited case studies as well as new projects being developed after the establishment of the SDGs often focus on how Earth observation data can be used for disaster prediction and management, land use, and climate change activities but often fail to examine the wider field in which disaster relief is a sub-set. For instance, the European Space Agency and the World Bank have a partnership currently to incorporate Earth observation data in 18 projects; all of which are large-scale resource management projects. There is also a lot of interest in incorporating Earth observation data into efforts to monitor progress on the SDGs. The Group on Earth Observation's Initiative 18 focuses on assessing and tracking the SDGs.

While these are important, perhaps even primary, areas of focus for global efforts to use Earth observation for in support of the SDGs, this paper seeks to look at how smaller scale projects and day-to-day practitioners can use Earth observation data to the advance the goals.

III. INTERNATIONAL DEVELOPMENT SECTOR

In order to fully realize its potential, Earth observation needs to be integrated into the common sources of information used by the daily practitioners and decision-makers in the field of international development. This field can be referred to as global development, international aid, foreign aid, and development assistance. Subfields in this sector include healthcare, governance, citizen organizing, education, gender, disaster preparedness, small- and large-scale infrastructure, poverty and livelihoods, human rights, forced migration, conflict resolution, and the environment clearly aligning closely with the SDGs. While many international development organizations respond to emergencies by providing or funding disaster relief and humanitarian aid, international development more broadly seeks to implement long-term solutions to problems by working to improve economic, political and social systems in sustainable way. Professionals in the field can include government officials, consultants, contractors, trainers, evaluators, researchers, and local practitioners.

Whether funded by federal government entities such as United States Agency for International Development, major grant-making organizations such as the Pew Charitable Trusts, or intergovernmental and international organizations such as the World Bank and the United Nation, international development projects are typically carried out as a partnership between the funding organizations, an implementing company or non-governmental organization (NGO), and local partners and government officials. This project dynamic shows multiple avenues for the transfer of knowledge and skills related to Earth observation in an efficient and cost-effective way. This paper looks how Earth observation technologies and data can potentially be used by numerous stakeholders and in all phases of the project lifecycle.

IV. CASE STUDIES

Most international development projects have a lifecycle that includes three phases: planning, implementation, and monitoring and evaluation. Earth observation data can be used as a resources in any, often all, of these stages. During planning development professionals define and plan for implementation of a particular development project by assessing needs, prioritizing options, and seeking funding or allocating resources. Geospatial technologies can be instrumental at this phase by providing improved situational assessment and allowing for more accurate interventions. Earth images can be used to demonstrate that there is a problem requiring intervention and to estimate its extent. In many cases, the projects themselves integrate the use of remote sensing data, such as creating complex maps to pinpoint intervention locations, track populations, or raise public awareness. Monitoring and evaluation, the development term for efforts to verify and then assess projects, has long taken into account the need for location-specific data gathering but has not begun utilizing the full range of available technologies. GIS and GPS are heavily used to in project verification often in combination with satellite images to create a visual assessment. The case studies below draw from all phases of the project lifecycle and represent contributions to a wide selection of the SDGs.

Rural Development

One of the primary purposes of the SDGs is to improve the lives of the most marginalized populations in developing countries. This often means rural communities with extremely low incomes and limited access to infrastructure and resources. Earth observation data can be useful tool for working within these types of situations. This case study looks at how satellite data can be used in planning of rural development projects in support of SDG 1 (No Poverty) and SDG 7 (Affordable and Clean Energy).

A group of researchers from the Massachusetts Institute of Technology and the IBM Thomas J. Watson Research Center developed a methodology for improving how the NGO GiveDirectly selects receipts for unconditional cash transfers in Kenya and Uganda. GiveDirectly serves as conduit for cash gifts from international donors to the poorest households in these countries on the premise that unconditional cash transfers allow recipients to make the best investments for their household and community and reduce donation inefficiency. Previously, the NGO had to make multiple rounds of site visits to select areas and households to receive cash transfers because government records do not extend down to the relative income level of rural villages. They use roof type, thatched or metal, as their main indicator of wealth.

The researchers used free Google Maps API images and relevant crowdsourced data and then applied imagery processing and machine learning techniques to determine the concentration and location of houses with thatched versus metal roofs. [6] This data was then used by GiveDirectly to distribute over $4 million dollars. The pilot in 2014 saved over 100 hours of planning time in addition to other costs and was relatively successful in identifying the poorest villages though it didn't perform as well in identifying the poorest individual houses due to a more complex village building habits than assumed. [7]

This same group of researchers also worked with the SELCO Foundation in India to use Earth imagery to better plan for setting up stand-alone micro-grids for electricity in very rural locations. The planning required to deploy these micro-grids is labor intensive and costly due to the lack of public sourced data on village layout. Using comparative data from previous efforts and commercial satellite including near-infrared measurements again combined with machine learning methods, the researchers were able to build maps of village structures and then run simulations on possible wiring topography to estimate costs. [8] This model can also take into account how the village might grow once the micro-grids are installed.

These case studies highlight two important points for consideration. The first is the importance of combining technical knowledge and methods with on-the-ground knowledge and expertise. The less useful results of predicting the poorest houses in a particular village came because researchers had not built in to the model the possibility of a family have a main structure with a metal roof and secondary structure with a thatched roof—a common practice in the villages to maintain a separate kitchen or to house unmarried sons. Secondly, these examples highlight how Earth observation is an important tool in using international development investment funds more efficiently by providing decision-makers and project planners with better information and reducing on-the-ground costs.

Community Mapping Projects

The broad nature of mapping initiatives contributes to many SDGs including 1 (No Poverty), 2 (Zero Hunger), 3 (Good Health and Well-Being), 4 (Quality Education), 5 (Gender Equality) 6 (Clean Water and Sanitation), 7 (Affordable and Clean Energy), 10 (Reduced Inequalities) and 11 (Sustainable Cities and Communities). Free, accurate map data can be a driver of economic development providing users better information on which to make planning and response decisions.

The Humanitarian OpenStreetMap Team, an NGO, employs crowdsourcing to build on satellite data to create accurate local maps for use in a variety of development projects. Essentially, remote sensing data is reduced to observable objects; then, these initial maps are completed by on-site volunteers and community members. For example, they've carried out extensive community mapping in Dar es Salaam as part of the Dar Ramani Huria project. Dar es Salaam, like many cities, lacks accurate maps and is largely an unplanned city with an insufficient infrastructure and services. It suffers from spillover issues including significant flood risk, limited access to services, and the easy spread of disease.

The NGO trains university students and local community members to create highly accurate maps of the city using simple and accessible technology, including GPS, field papers, and the OpenStreetMap system. After creating the maps, project members then present the maps to communities and stakeholders in each ward. All final data is freely accessible online to anyone. The effort began by mapping the most flood-prone areas of the city and is now expanding its work to other wards and with additional detail and resources. Prior to the advent of this project, it could be difficult to locate specific project sites or even to assess what projects might be needed.

One of the main target users are ward officers, the local authorities managing public works. Ward officers have already used the maps for new urban planning related to roads, drainage, electricity distribution and water supply as well as public service provisioning such as health centers and schools. [9] During a cholera outbreak in August 2015, the ward officer of Tandale ward used the maps provided by Ramani Huria to identify the location of the victims within the ward. [10] The maps gave him detailed information on water points and sanitation infrastructure, thus allowing his team to better investigate the sources of the outbreak.

Projects such as these demonstrate the interconnectedness of development projects and of the SDGs themselves. Outside donors supported the mapping efforts which brought in international experts to train a local cadre of students and community members who will then go on to continue working with the local government officials. Other NGOs interested in making contributions now have better assessment and planning tools as they create new projects. This kind of community project also support the empowerment of local actors and can even be targeted at specific vulnerable groups such as the disabled, women, or youth as a means of providing skills economic and social advancement. SDGs cannot be addressed in a vacuum; rather, efforts to improve one aspect of living conditions will affect many aspects.

Small-Scale Forest Monitoring

Earth observation is often used for government or international efforts to monitored land use, including tracking deforestation. However, the same data can be used by smaller localized projects looking at forest cover as it relates to livelihoods, agroforestry initiatives, and even illegal activities. Therefore, this case study highlights how Earth observation can support SDG 2 (Zero Hunger), 15 (Life on Land), and 16 (Peace, Justice and Strong Institutions).

Since the collapse of Somalia's central government in 1991, militia groups have been fighting for control of the country. Resources to finance these ongoing fights come in part from illegal charcoal exports. [11] Extensive production of charcoal has led to rapid tree cover loss. [12] Deforestation accelerates the process of desertification, which reduces access to land for agriculture or cattle grazing resulting in population shifts as locals cannot maintain their livelihoods. [13] Rapid changes like this are also likely to lead to worsened environmental conditions such as drought and flooding. [14] The ongoing instability stretching back more than 20 years makes it very difficult for researchers to conduct field studies to assess the extent of environmental damage.

Researchers at the World Resource Institute developed a method to map and estimate the impact of illegal charcoal production in southern Somalia—an important step in designing future projects. Using high resolution satellite imagery, they created a semi-automatic detection method to ascertain charcoal production sites. Their initial analysis revealed an average production of 24,000 tons of charcoal together with a tree loss rate of 2.7 percent during the two-year period included in the study. [15]

Ultimately, this information can be used by various groups to make better informed decisions on how to address illegal activities and worsening livelihoods in Somalia. Despite the instability, many NGOs and other stakeholders carry out programming in Somalia. Without accurate information about the most acute needs, their efforts will be less effective. Additionally, as the UN and others work to end the illegal export of charcoal, data on the extent of the trade will be essential.

Related, this same type of data analysis can useful when forestation programs are already underway. The NGO, Plant With Purpose, and its local affiliate, Floresta-Tanzania, use the normalized difference vegetation index to assess the impact of their farming practices projects. They provide training and technical support to help communities establish savings groups to employ sustainable farming techniques such as agroforestry and environmental conservation practices such as reforestation and watershed protection. [16] When they analyzed forestation over a 5-year period of time using publicly available Earth observation data, they found a strong positive trend between vegetation levels where savings groups are present compared with where they are not. [17]

This case study highlights satellite imagery and analysis, though well documented as a source of information about large-scale environmental changes such as deforestation, also has a role to play in smaller organizations and when access to the area is restricted, both for planning and evaluation of projects.

Human Rights Advocacy

Since the data became commercially available in the 1990s, multiple groups have been exploring how the analysis of satellite imagery can be used for humanitarian and human rights purposes. The uses are wide-ranging and well-documented and will be important factors in achieving SDGs focused this topic. Within SDG 16 (Peace, Justice and Strong Institutions), there are multiple distinct objectives that can be supported by Earth observation data. This case study on human rights advocacy looks specifically at objectives 16.1 (Significantly reduce all forms of violence and related death rates everywhere) and Objective 16.3 (Promote the rule of law at the national and international levels and ensure equal access to justice for all). It also looks at how this same kind of analysis can be used in service of SDG 11 (Sustainable Cities and Communities), specifically objective 11.4 (Strengthen efforts to protect and safeguard the world's cultural and natural heritage).

The American Association for the Advancement of Science (AAAS) Geospatial Technologies and Human Rights Project works to expand the applications of geospatial technologies to human rights monitoring. By conducting numerous case studies all over the world ranging from mass grave detection to forced relocation to property destruction, this project has demonstrated the utility of using available satellite technology to verify and assess human rights violations. [18] Satellite images are used to crosscheck reported incidences for confirmation of occurrence, extent, and timing. This type of work is a recognized and documented uses of geospatial information. However, they've also pioneered how geospatial analysis might be used in human rights-related litigation at the regional and international levels. Human right advocacy is not just about short-term cessation of hostilities or adverse condition but about improving legal accountability and the capacity of institutions to respond to human rights abuses.

In August 2008, AAAS staff, at the request of Amnesty International, reviewed satellite imagery of the Tskhinvali region of South Ossetia in Georgia. This effort was spurred by concerns during the conflict between Russia and Georgia over the regions of South Ossetia and Abkhazia between August 10 and August 19. They documented that by August 19, a broad range of violence had occurred around the village areas of Tskhinvali and multiple signs of military actions. [19]

In 2009, AAAS analyzed images of the Nakhchivan region of Azerbaijan to determine if reports of Armenian burial monuments. This occurred following a request by the United Nations Educational, Scientific and Cultural Organization and the European Union to carry out a fact-finding mission which was denied by the government. AAAS found significant changes to the terrain including the absence of the artifacts indicating that accounts of their destruction were likely correct. [20]

In 2012, in partnership with Human Rights Watch, AAAS investigate concerns about whether the government was relocating rural population of agro-pastoralists who practice shifting cultivation into small, permanent settlements in the Gambella region of western Ethiopia. Their analysis of high-resolution imagery confirmed the likelihood that villagers had been forced into a more permanent settlement and that arable land available for the population decreased. [21]

These case studies show a number of best practices as well as barriers. The first case study highlights an instance where the exact imagery needed was unobtainable. No directed satellite slots were available for purchase at the time of the conflict in Georgia forcing AAAS to perform its analysis from variety of high-resolution imagery sources, with spatial resolution of one meter or better. [22] Given how satellite time is apportioned with the government and large-scale commercial buys receiving priority, this could be a significant challenge for international development projects that need highly specific imagery.

All of the case studies demonstrate the importance of experienced technical geospatial experts as part of international development projects. This kind of high resolution analysis is difficult, suffers from unclear information on incident locations especially when access to ground locations is restricted, and must be confirmed to a high degree of accuracy for use in publications or legal processes. Though not all geospatial analysis requires this level of technical skill, as Earth observation data is used more commonly, it's important to focus on maintaining high quality, accurate analysis as a best practice.

Third, this case study shows a longer-term use for geospatial analysis of human rights situations. The Independent International Fact-Finding Mission on the Conflict in Georgia, commissioned by the Council of the European Union, included AAAS analysis in its findings. Many organizations have used Earth observation analysis to bring attention to these conflict and humanitarian situations. In the justice system, satellite imagery is generally accepted as a secondary source of information, meaning that satellite imagery analysis can "provide corroborative evidence to help evaluate the accuracy of reported incidents or claims from sources of unknown reliability." [23] This year, the International Criminal Court authorized an investigation of potential war crimes and crimes against humanity during the armed conflict between Georgia and Russia. They also held their first trial dealing with the destruction of a cultural heritage site. Satellite imagery can play an important role in these types of cases but more must be done to increase understanding among judges and other relevant court personnel of the value and appropriateness of remote sensing analysis.

Democracy and Governance

Though not an obvious application, Earth observation data can be used in a variety of ways to support of SDG 10 (Reduced Inequalities) specifically target 10.2 (By 2030 empower and promote the social, economic and political inclusion of all irrespective of age, sex, disability, race, ethnicity, origin, religion or economic or other status) and SDG 16 (Peace, Justice and Strong Institutions) specifically targets 16.6 (Develop effective, accountable and transparent institutions at all levels) and 16.7 (Ensure responsive, inclusive, participatory and representative decision-making at all levels). To be successful, sustainable development efforts to improve living conditions must include a strong focus on promoting effective governance and accountable institutions. Support for free and fair elections is a key component of that strategy, and Earth observation data could be an incorporated in many ways to enhance the efficacy of projects.

For instance, satellite imagery and maps could be use pre-election to improve the logistics and planning of elections in developing countries. It could be used to conduct an informal census in rural areas to confirm official numbers and inform better distribution outreach efforts. It could assist in setting election district boundaries and polling station locations to maximize potential voter turnout. Weather and topography information can help in figuring out when to hold an election in countries or regions that experience extreme weather or have difficult terrain. Simply getting elections materials to remote areas can be difficult, and satellite data could be used to improve those efforts. Most importantly, remote sensing data could be used to document the election itself and improve public confidence in outcomes. Such documentation could be used to confirm whether a polling station was actually open and to estimate voter turnout. This impartial data also could be used as confirmation of eye witness accounts if election-related violence does occur.

In Kenya, ethnic violence broke out after disputed presidential election held on December 27, 2007. The United Nations used satellite imagery and maps to confirm reports of violence and help execute relief efforts. Fire is often a tool used to drive citizens from their homes and create panic, so the UN used active burn locations as an indicator of where violence was occurring. [24] They were able to confirm details such as the timeline for the escalation of violence and the fact that the first outbreaks of violence occurred in locations where non-indigenous populations were living. [25] There were limitations to the analysis including the inability to determine levels of violence especially between rural and urban locations, and that some violence occurred that did not involve fires. [26] These maps not only assisted in addressing immediate concerns but assisted in post-violence analysis for longer-term elections safety.

Another example of work being done in democracy and governance is the Afghanistan Open Data Project. This pilot is a community effort to publish a combination of political, social, and economic datasets of significance to elections in Afghanistan. Available data sets range from maps showing the distance to registration centers to geographic analysis of alleged irregularities and electoral complaints. Graphics can be an important confidence boosting measure regarding future elections. For instance, by showing all polling stations that Afghanistan's election commission planned to audit for fraud, based on which stations reported the maximum number of votes, demonstrates commitment to improved results and increase the legitimacy of government.

This case study highlights an area where donors are less willing to invest in part due to a less familiarity with the usefulness and reliability of remote sensing data. Cost is also a factor as many proposed projects would need to purchase day and location specific images, potentially for a high number of sites. The utility of a group like Development Seed, which supports the Afghan Open Data project, is also important. The number of individuals who can bridge the knowledge gap between technical field experts and technological expertise is increasing but is still rare. Additional pilot projects have been proposed and will be key to demonstrating the importance of satellite data to improve decision-making for large events such as elections.

V. Challenges and Barriers

Despite general recognition that Earth observation and geospatial technologies will be critical for achieving the SDGs, challenges remain for wider adoption.

Cost and Licensing

Depending the scope and needs of the project, imagery costs can be high. In a field highly dependent on donor organizations and generally operating under not-for-profit status, this barrier is significant. Licensing can also be hard for NGOs and other stakeholders to navigate. Incorrect re-use of obtained images does occur. Each image provider has different requirements further complicating the process.

Some projects can make use lower resolution images available from public sources such as Landsat or Google Earth while others require high resolution images available only from commercial sellers. Some organizations build these costs into their project proposals. However, smaller groups, or those with less experience using of geospatial information may have difficulty obtaining donor support.

One option could be for a consortium of large development organizations to pool together to purchase and hold the licensing for useful images. However, the non-standard data needs across the sector make it difficult for any one solution to be complete effective.

Technical Capacity

The field of international development is composed of individuals from a large variety of backgrounds ranging from government to social sciences to technical sciences. And although there many who specialize in technology applications and geospatial analysis specifically, their numbers are limited within the wider field. There is often an understanding that this data could be helpful without the knowledge or resources to explore how to make that happen. Projects by USAID, the UN, and others seek to provide resources but disseminating these to all who could benefit remains a problem. Further, certain types of analysis simply cannot be performed credibly by anyone other than fully trained technical analyst. Focused efforts to increase awareness at the level of decision-makers within all types of organizations in the field and to continue to provide more user-friendly resources for practitioners will be key to the better use of Earth observation data in international development.

Limits of Data

Most satellite images are based on optic imagery which cannot see through clouds, tree, or at night. Satellites also do not cover all areas of the Earth continuously and are not always available for tasking. Though increased use of mobile phones world-wide has greatly diminished the problem of accuracy in location for pulling the needed image, this also remains a challenge. Further, large images and data sets require specialized software and storage capacity.

Data privacy is also a special consideration. This can include problems surrounding the privacy and protection of data, informed consent within a digital data/open data framework, the risk of unauthorized data dissemination, and general lack of institutional policies with regard to digital data.

Though many free platforms and software are becoming available, these still require training and specialized knowledge to use efficiently. As more solutions are found to overcome these limitations, it's important that dissemination and outreach efforts occur to the wider field of international development professionals.

Donor Skepticism

Although many funding organizations are open to new and innovative approaches to projects, many are not. Lack of familiarity with Earth observation data can lead to projects remaining unfunded. There is also a tendency in the industry to believe that "data" is the providence of evaluation experts rather than useful across the entire project lifecycle. Continued sharing of use cases and improved collaboration across all stakeholders will help alleviate this problem.

VI. CONCLUSION

This paper explored many innovative ways that Earth observation data and geospatial analysis can be used widely in the field of international development to help achieve the Sustainable Development Goals. Geospatial data are routinely cited as key for projects focused on disaster management and climate change but less attention is given to the full range of possibilities. This paper looked at several case studies to highlight applications, best practices, barriers, and potential solutions. One of the most important steps needed to promote increased use of Earth observation data is improving cross-sector dialogue between the various stakeholders of international development and the space community. Practitioners need more awareness of the usefulness of Earth observation data and additional resources for making use of it.

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