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A review of applications of satellite earth observation data for global societal benefit and stewardship of planet earth

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A R T I C L E I N F O

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A B S T R A C T

Remotely sensed data can be used to understand and devise measures to address important global issues such as climate change, disaster and disease outbreak. National Aeronautics and Space Administration (NASA) is one of the largest producer and gatekeeper of satellite earth observation (EO) data that plays a crucial role in ensuring that these resources are used for solving global societal problems. However, the extent of remote sensing application is highly disparate in different parts of the world. This paper provides a general overview of key societal applications that have been enabled globally with the use of EO data. It also summarizes the impact of various NASA-supported programs for promoting applications on the targeted beneficiary communities. The themes addressed here are land cover/land use mapping, carbon biomass assessment, food security, disaster management, water resources, ocean management and health and air quality. The paper also argues for capacity building that is crucial to building sustainable solutions when using EO data for science-based decision making.

1. Introduction

Remote sensing is the science of obtaining information without physically being in contact with it. This process involves detection and measurement of radiation at different wavelengths reflected or emitted from distant objects or materials, by which they may be identified and categorized by class/type, substance, and spatial distribution. Through various remote sensing platforms such as satellites and aircraft, supplemented by surface and subsurface measurements and mapping, Earth's physical, chemical, and biological systems can be obtained, which is collectively known as Earth Observation (EO) [2].

The capacity of satellite remote sensing and satellite technology is distributed quite disproportionately in the world. As of November 2015, only 74 countries have been able to make satellite launches independently or with the help of others (see Fig. 1; [4]. Out of the satellite launches since 1962, more than 320 have been EO satellites launched worldwide covering the atmosphere, oceans, land, and other Earth systems. The United States, Russia, France, Italy, and Germany are at the forefront of the EO satellite launches. They are followed by China, India, Canada, Brazil, Argentina, South Africa, Nigeria, and Australia [7].

The history of earth observation began in 1840s, during the era of geographical exploration, when pictures were taken from cameras secured to the tethered balloons for the purpose of topographic mapping. It took a further 100 years for earth observations to evolve to a platform based in space called satellites. In 1958, the National Aeronautics and Space Administration (NASA) was established. Much of the technological advances in human and robotic space flight had already started in response to the early Soviet space achievements [13,14]. Initially, a lot of the applications were defense-centric. Later, NASA missions like Environmental Science Services Administration (ESSA) and Synchronous Meteorological Satellites (SMS) came on board to improve meteorology and weather science. The first major land monitoring camera system from the sky, called Landsat mission, was launched in 1972. It has produced over 2 million images since the first launch. In 2008, a new era of open-access satellite data began when the US Geological Survey (USGS) publicly released its Landsat archive, dating back from the 1970s. Currently, this is believed to be the world's largest collection of Earth imagery [2]. This availability of open source data has also helped developing countries that are not capable of launching or maintaining their own EO satellite but are in dire need of remotely sensed data to solve problems.

NASA has been an important catalyst for international cooperation in changing the mindset of how and why humans need

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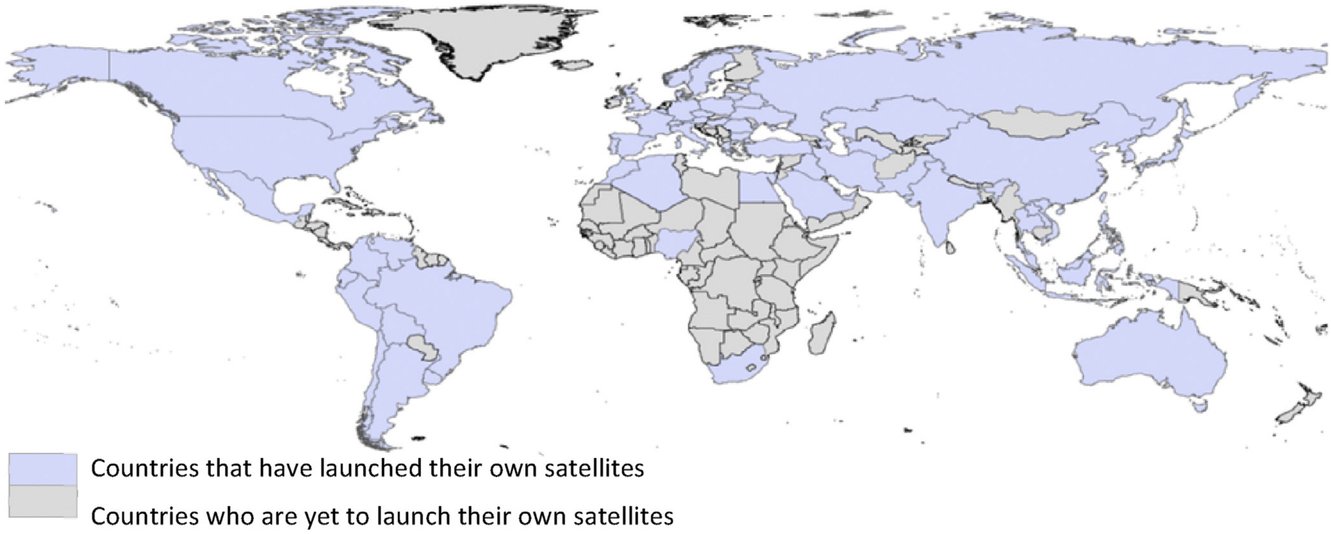

Fig. 1. As of November 2015, 74 countries have launched their own satellites indigenously or with the help of others. Map was compiled from various data sources in the public domain.

"space" as the final frontier for stewardship of Planet Earth [13,14]. When the National Research Council (NRC) completed its first decadal survey in 2007 for Earth science and applications for NASA and National Oceanic and Atmospheric Administration (NOAA), and USGS, it highlighted the need of the U.S. government to work in concert with private sector, academe, the public, and its international partners in renewing the EO systems and restoring leadership in Earth and science applications. That survey set a new agenda for satellite EO missions in which practical societal benefits were of an equal importance as were the efforts in acquiring new knowledge about Earth.

Fig. 2 shows select programs that NASA launched in the past 5 years that have direct societal benefits associated with its science focus area. The goal of all these missions are to find answers to how the global earth system changing, how will it change in the future, and how does the Earth system respond to natural and human induced changes – all driven by the need to make planet earth a more sustainable place for humans to live with other forms of flora and fauna [13,14] (see Fig. 3).

However, greater access to remote sensing data has not necessarily translated to greater utilization of the EO data to its full potential for the global society. Although remote sensing data has great potential for science-based decision-making on critical areas such as disaster management, global environment, and management of natural resources, not all users (policy makers, academic institutions, organizations in various countries) have the necessary technical background and knowledge to understand, download, and manipulate the data according to their needs. This is especially the case for developing nations where the potential of EO for the societal applications is yet to be appreciated in its full merit. These are the countries where EO data are a clear surrogate for traditional methods of gathering data that are cost intensive or fundamentally impossible.

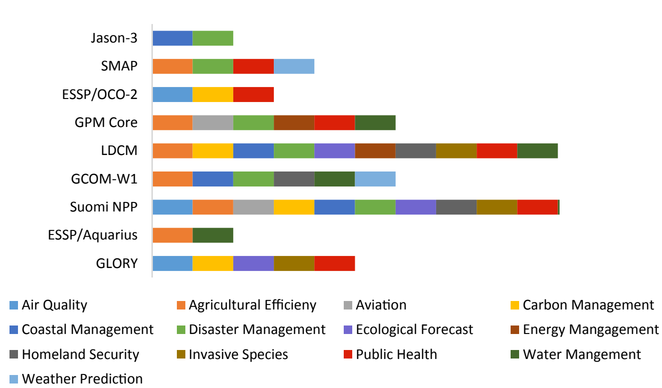

Fig. 2. Select NASA missions[11] from 2010 to 2016 that has direct application on societal benefits listed above. Data adapted from http://eospso.nasa.gov/files/mission_profile.pdf [13,14].

To realize the fullest potential of EO data, various international organizations have developed programs to help make the use of remote sensing data more widespread. SERVIR (Spanish for "to serve") is one such program that has played a major role in spurring programs that use remotely sensed data for various critical programs in developing countries. It was originally established in 2004 as a joint venture between NASA and the U.S. Agency for International Development (USAID). SERVIR provides satellite-based EO data and science applications to help developing nations in providing critical information in order to assess environmental threats and damages from natural disasters. It first started in Central America, expanded to East Africa in 2008, to Hindu-Kush-Himalaya (HKH) in 2010. In 2015, the Lower Mekong region was also brought under the SERVIR umbrella in partnership with Asian Disaster Preparedness Center (ADPC) where the application is primarily focused on disaster risk management (DRM) and disaster risk reduction (DRR).

After the first decadal survey [3], programs were identified to enable better interaction between satellite mission scientists and relevant communities from the initial development phase so that mission data products were of maximum value. One such program is the Early Adopter (EA) program by NASA Applied Sciences Program (ASP). Subsequently, the first Early Adopter Program was developed for NASA's Soil Moisture Active Passive Mission (SMAP) in 2010. The goal of EA program is to facilitate feedback on mission products during pre-launch, and to accelerate the use of these products during post-launch by providing specific support to Early Adopters who commit to engage in applied research [5]. Most of the Early Adopters are currently from academic institutions, international organizations and government entities in developed countries. However, if the Early Adopter Program reaches out to all the