IAC-19-B1.5

SERVIR: Leveraging the Expertise of a Space Agency and a Development Agency to Increase Impact of Earth Observation in the Developing World

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Abstract

SERVIR is a joint initiative of the National Aeronautics and Space Administration (NASA) and the U.S. Agency for International Development (USAID), in collaboration with leading technical organizations around the world--called SERVIR hubs--that serve and empower developing countries to use satellite data addressing critical challenges in food security and agriculture; water and water-related disasters; land cover, land use and ecosystems; and weather and climate. Over the past fourteen years, the program has worked with stakeholders in 50 countries across the world, partnered with 390 institutions, and generated and shared over 70 products from 27 satellites and sensors. In that process, around 7,400 specialists have been trained in the application of Earth observation data and technology. In its lifetime, SERVIR has been agile and innovative in shifting from what was essentially an incubator for testing and deploying Earth observation science and technology to making co-development the hallmark of its work, exemplified by both South-South and North-South scientific collaborations. SERVIR's approach has embodied the concept that to solve really big problems, big, creative solutions are needed. SERVIR represents the world working together to address environmental challenges using spaced-based and geospatial technologies.

Aligning with the very meaning of SERVIR, i.e. "to serve," the program continues to be demand-driven in developing and deploying services (versus one-off products) which address development challenges using geospatial tools and Earth observation science. In 2016, as part of SERVIR's evolution, USAID and NASA released the 'SERVIR Service Planning Toolkit,' a guidance document which provides a framework for how geospatial services can be used to tackle development challenges in a sustained manner. Since then, the Service Planning Toolkit's systematic approach has begun to catch on in other Earth observation efforts. To improve access and use, SERVIR launched a Service Catalogue in February 2019, a searchable collection of demand-driven geospatial services that use Earth observations to support decision making.

SERVIR implementing hub partners –include SERVIR-West Africa at the Agrometeorology, Hydrology and Meteorology (AGRHYMET) Regional Center, in Niamey, Niger; SERVIR-Eastern & Southern Africa at the Regional Centre for Mapping of Resources for Development in Nairobi, Kenya; SERVIR-Hindu Kush Himalaya at the International Centre for Integrated Mountain Development in Kathmandu, Nepal; SERVIR-Mekong at the Asian Disaster Preparedness Center in Bangkok, Thailand; and SERVIR's newest hub, SERVIR-Amazonia, at the International Center for Tropical Agriculture (CIAT) in Cali, Colombia.

Keywords: SERVIR, Earth observation, developing countries, applied science, capacity development, USAID

Acronyms/Abbreviations

Agrometeorology, Hydrology and Meteorology (AGRHYMET)
Applied Sciences Team (AST)
Asian Disaster Preparedness Center (ADPC)
International Center for Tropical Agriculture (CIAT)
Food and Agriculture Organization (FAO)
Global Precipitation Measurement (GPM)
Google Earth Engine (GEE)
International Centre for Integrated Mountain Development (ICIMOD)
Marshall Space Flight Center (MSFC)
Moderate Resolution Imaging Spectroradiometer (MODIS)
National Aeronautics and Space Administration (NASA)
Regional Centre for Mapping of Resources for Development (RCMRD)
SERVIR Annual Global Exchange (SAGE)
Synthetic Aperture Radar (SAR)
U.S. Geological Survey (USGS)
United States Agency for International Development (USAID)

1. Introduction

A joint development initiative of the National Aeronautics and Space Administration (NASA) and the United States Agency for International Development (USAID), SERVIR works in partnership with leading regional organizations worldwide to help developing countries use information provided by Earth observing satellites and geospatial technologies. SERVIR creates tools, products, and services that empower decision makers to better address critical issues related to food security, water resources, natural disasters, land use, and climate variability.

Since its launch in 2005, SERVIR has grown into a global network of five active hubs that are improving awareness, increasing access to information, and supporting analysis to help people across Africa, Asia and South America to better manage today's complex development and environment challenges. With activities in more than 50 countries and counting, SERVIR has already developed over 70 custom tools, collaborated with 390 institutions, and trained around 7,400 individuals, improving the capacity to develop local solutions.

In Bangladesh, the government's Flood Forecasting and Warning Center can generate earlier forecasts to predict river flooding, thanks to river level data collected by satellite. In Eastern and Southern Africa, analysts now have access to satellite-based land cover maps that increase the accuracy of agriculture and conservation monitoring. In Southeast Asia's Lower Mekong region, scientists and development practitioners now wield the power of Google Earth Engine to process big data in seconds instead of months, enhancing environmental management and sustainable development planning. These are a few examples of the many activities around the world supported by SERVIR. Through the combined efforts of the five regional hubs, and with technical support from USAID, NASA, and U.S.-based science collaborators, SERVIR is at the forefront of demonstrating the value of using Earth observations and geospatial data, products, and tools to advance international development through science and technology.

2. SERVIR NASA-USAID Partnership

The U.S. Agency for International Development (USAID) and the National Aeronautics and Space Administration (NASA) are U.S. Government agencies that have very different missions, yet working together since 2005, have forged a partnership and achieved goals that would not have been possible independent of one another. NASA and USAID provide the foundation that is the SERVIR Program that partner with organizations that "Connect Space to Village" around the world.

Among NASA's goals is to improve life here on Earth as well as exploring space and beyond[1]. When humans first went to the moon, they witnessed Earth rising above the horizon of the moon, and this gave people a different perspective of a small fragile blue planet. From the vantage point of space, space agencies have continued to improve their capability to look back at the Earth to understand it. Through a constellation of satellites, Earth observation data is made free to the public. NASA's primary goal for SERVIR is to provide the best and most appropriate science, and SERVIR facilitates NASA implementing applied science around the world with expert participation from the partnering regions. Local organizations and scientists play a key role in providing knowledge of their region as well as their specific application need.

USAID's mission strives to end extreme poverty and promote resilience in developing countries[2]. which it does through an extensive network of in-country assistance program and local staff and offices that work with local partners. USAID partners with local authorities and communities to address issues such as food security, natural resources management, health, and humanitarian assistance that require good data in places that are often very data-limited.

3. Global Network Partnerships Through SERVIR Hubs

SERVIR brings together a variety of specialists from diverse backgrounds to create a unique team for addressing complex environmental issues and providing solutions to local decision makers and stakeholders around the globe. The heart of this team is SERVIR's global network of five leading regional knowledge centers, or hubs—the Regional Centre for Mapping of Resources for Development (RCMRD) in Nairobi, Kenya; the International Centre for Integrated Mountain Development (ICIMOD) in Kathmandu, Nepal; the Asian Disaster Preparedness Center (ADPC) in Bangkok, Thailand; the Agrometeorology, Hydrology and Meteorology (AGRHYMET)* Regional Center in Niamey, Niger, and the most recent hub addition, the International Center for Tropical Agriculture (CIAT) in Cali, Colombia — as well as hub consortium members and other partners dedicated to building resilience through the integration of Earth observations and geospatial technologies. In addition to the hubs, the SERVIR team includes the SERVIR Science Coordination Office, NASA Headquarters and centers in the United States, USAID Washington and missions around the world, a competitively selected SERVIR Applied Sciences Team enabling innovative science to

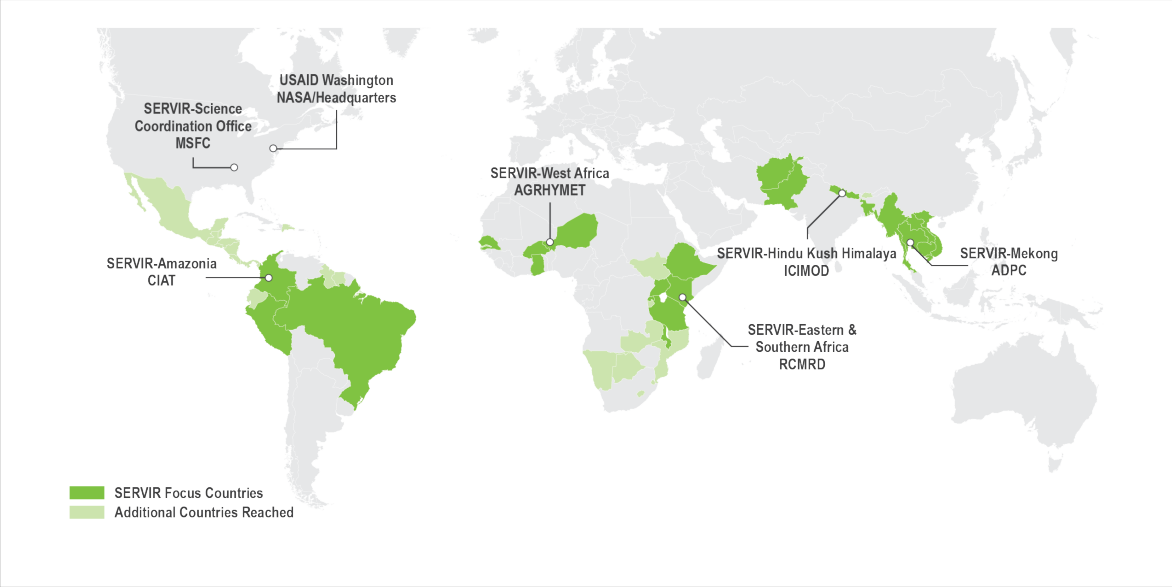

Fig. 1. 2019 SERVIR Map

the network, and a SERVIR Support Team which coordinates hub exchanges, knowledge management, small grants, and communications.

Building and relying upon this growing network of partners is fundamental to SERVIR. Beyond the sponsorship and active participation of NASA and USAID, SERVIR collaborates with a number of other U.S. government agencies and projects as well as government agencies in SERVIR regions. SERVIR also engages in joint research with universities and nongovernmental organizations, and promotes capacity building with these expert groups.

4. Collaborations and Private Sector Partnerships

As the SERVIR network grows, developing new partnerships that tap into the expertise, resources, and innovations of a diverse array of organizations across the public, private, and nonprofit sectors will be critical to sustaining and strengthening our ability to bring cutting-edge solutions to development challenges in hub regions.

Drawing on the strengths of multiple U.S. agencies and a global network of partners, the **SilvaCarbon Program** provides targeted technical assistance to build country capacities for measuring, monitoring, and managing forest and terrestrial carbon. SERVIR is collaborating with SilvaCarbon to strengthen the capacity of hubs on forest mapping and monitoring, including biomass estimation, by capitalizing on currently underutilized Earth observation resources, such as Synthetic Aperture Radar (SAR) datasets in developing new products. SERVIR, in a joint collaboration with SilvaCarbon, published *The SAR Handbook: Comprehensive Methodologies for Forest Monitoring and Biomass Estimation* in April of 2019 and made it available to the public. The SAR Handbook is an actionable guide that focuses on the application of SAR data for forest monitoring and biomass estimation with step-by-step tutorials that include open source scripts. Just within 5 months of release, the SAR Handbook has been downloaded 227K+ times in 169 countries around the globe, which will enable improved monitoring of forest resources.

Tracking the Earth's rapidly changing landscapes efficiently and accurately is critical to protecting lives and livelihoods. Satellite technology provides a unique vantage point for observing our land, oceans, atmosphere, and many other elements of the environment. For decades, access to this technology for effective decision-making has been a strenuous endeavor for scientists and development practitioners across the globe, requiring high processing computers, access to vast compendium of images, and technical expertise in advanced algorithm development, all of which require significant financial and technical resources. Now, through a unique partnership with **Google**, SERVIR-Mekong is changing this reality for scientists and development practitioners across the Lower Mekong region by leveraging Google's cloud-based, high computing platform called **Google Earth Engine** (GEE). In partnership with the **University of San Francisco, U.S. Forest Service**, and **SilvaCarbon**, SERVIR-Mekong developed, tested, and delivered a GEE curriculum that served as the backbone for a regional training event for 38 scientists in Bangkok in July 2016. With three introductory courses completed, more than 100 scientists have been trained across the

region, with a train-the-trainers approach aimed at promoting sustainability and continued capacity building. At the SERVIR hubs, the curriculum has been reused and customized for additional national and regional level trainings in South and Southeast Asia, Eastern and Southern Africa, and West Africa. These trainings are empowering scientists with state-of-the-art skills that directly guide decision makers in their environmental management and sustainable development planning.

SERVIR is also partnering with the **U.S. Forest Service, Spatial Informatics Group**, and the **Food and Agriculture Organization (FAO)** of the United Nations to jointly develop a free and open online version of Collect Earth. Called Collect Earth Online, and built on top of GEE, it includes new features, capabilities, and functionality to collect ground validation data for improved land cover analysis. This new global tool, which was scaled up from an initial SERVIR-Mekong regional service, will assist **Silva Carbon** and the **Global Forests Observation Initiative** by adding value to existing platforms and supporting countries in reducing emissions from land use and land use change.

Through SERVIR, NASA, USAID, and the SERVIR hubs have expanded the use of Earth observation data around the globe, provided training and information sharing, and developed products, tools, and services to build capacity and connect more people to do science. Even more important, the science and its application have helped people react better and faster to help people live better lives and build resilience into their communities. Some significant SERVIR statistics can be seen in Figure 2.

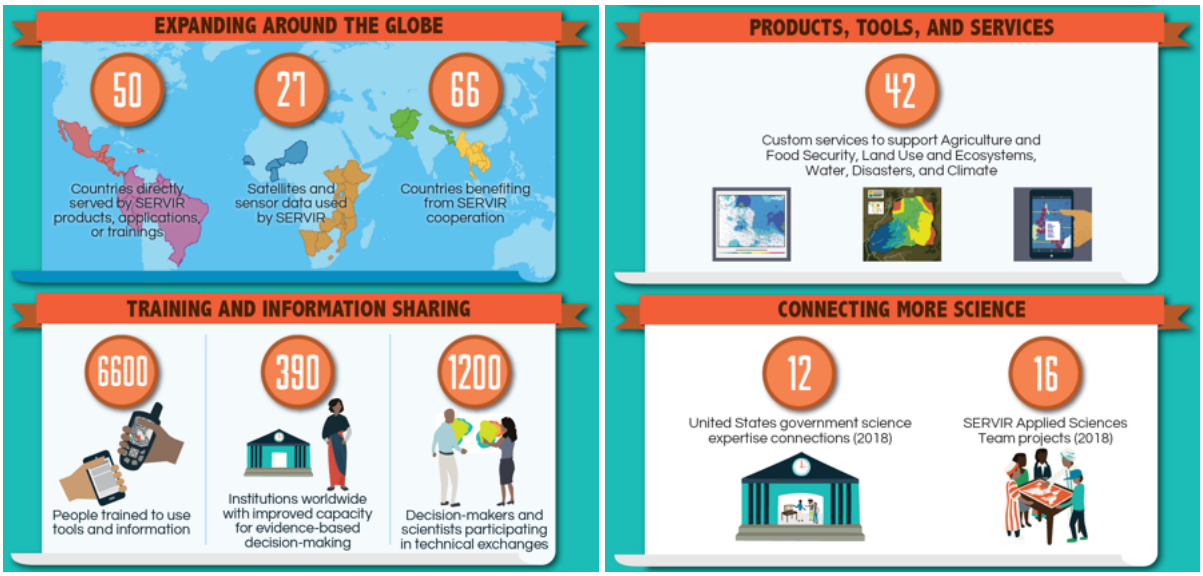

Fig. 2. SERVIR by the numbers (at the end of 2018)

5. Earth observation: Satellites, Sensors, and Technology

Earth observation science is one of the key critical elements for SERVIR. The first remote sensing event of Earth was the very first artificial satellite launched into space. In 1957, Sputnik sent back radio signals and scientists were able to learn about the ionosphere. Since then, NASA technology in Earth observing satellites has advanced to provide more frequent and better observations of the Earth, which has been provided to the public for free use. Other nations and their space agencies have also launched satellites, some of which are sharing their data freely and openly. In addition to the Earth observation data, computing power and machine learning is also


Fig. 3. GPM Core Observatory satellite (NASA/Britt Griswold)

advancing the ability to ingest and analyze huge amounts of data that is being collected. With a steady resource of reliable Earth observation data to study our planet, SERVIR facilitates the expertise to apply this information for practical use in developing countries. SERVIR uses data from 27 satellites and sensors (see Table 1).

Below are some examples of how SERVIR tools and services are developed with satellites and sensors from space. SERVIR-Eastern and Southern Africa, working with the University of Maryland, College Park, has developed Landsat-based crop masks and a GIS-based sampling frame to enable the Kenyan Crop Insurance program to expand coverage across the country. SERVIR-Hindu Kush Himalaya uses inputs from the Global Precipitation Measurement (GPM) mission, ensemble models, Landsat, MODIS and other data sources to support weather monitoring with the High-Impact Weather Assessment Toolkit co-developed with NASA MSFC and Brigham Young University. SERVIR-Mekong uses Landsat data for land cover monitoring. This system produces Landsat-based, high-quality regional land cover maps and identifies annual land cover changes in the Lower Mekong region. The West Africa hub's services leverage NASA / USGS Landsat-8 and Copernicus Sentinel-2 data for their ephemeral water body monitoring service, and Landsat-8 and Copernicus Sentinel-1 and -2 data for their illegal mining monitoring service.

In SERVIR hub regions, there is a critical need for satellite and model-derived rainfall data for predicting droughts, estimating crop yields, and more. Decision makers need a way to accurately assess how severe a drought will be, how it compares to past droughts, and its potential effect on crop yields. It is important to place an evolving drier-than-normal season into historical context in order to analyze the severity of rainfall deficits. Until now, such analyses used rainfall data from ground observations at specific locations, but long-term ground observations are sparse, and further, fails to show the region-wide variability that reveals comprehensive rainfall patterns. SERVIR supports the inclusion of ensemble model forecast data, as well as historical ground-based data, in combination with satellite data to help give decision makers a better overall picture when making historical context assessments. Several high-quality historical and model-derived forecast datasets exist, at the global scale, that can help with these challenges. But analyzing these datasets, especially in areas with limited internet accessibility, is often impossible. To bring these datasets together, SERVIR developed a web-based tool called ClimateSERV that allows development practitioners, scientists, researchers, and government decision makers to easily subset, analyze, visualize, and download historical rainfall data, vegetation condition data, and seasonal forecasts (180 days) of rainfall and temperature to improve understanding of conditions, and inform decision-making related to agriculture and water availability. ClimateSERV gives anyone the ability to assess and monitor large-scale rainfall patterns and to analyze how those patterns may be affected by climate variability, determining the likelihood of drought, and tracking crop conditions.

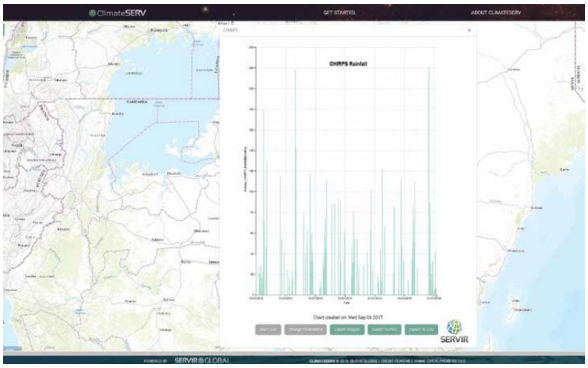

Fig. 4. ClimateSERV (historical rainfall, vegetation condition, and 180-day rainfall forecast)

6. SERVIR's four thematic service areas

Agriculture and Food Security - the food security thematic service area includes agriculture, rangeland management and pastoralism, and fisheries and aquaculture, particularly through the lens of adaptation to increasing environmental extremes. Key topics include linking agricultural productivity assessments, crop yield models, and use of climate scenarios for assessing the impacts.

Land Cover - the land cover, land use change and ecosystems thematic service area focuses on sustainable landscapes through natural capital accounting and ecosystem services. Ecosystem services are critically dependent on natural capital such as forests, the quality of soils, organic and nutrient contents, topography, rainfall, and land cover among other factors.

Water and Disasters - the water resources and hydroclimatic disasters thematic service area includes water quantity (including groundwater), sediment transport, water quality, and water-related disasters. It involves improved estimation and predictability of water resources for integrated water management. Key topics also include estimations of water allocations, the food-water-energy nexus, and disaster

investigations including floods, droughts, and rainfall-induced landslides.

Weather and Climate - the weather and climate thematic service area spans a continuum of time scales, ranging from short-term prediction of weather, through seasonal forecasts, to interannual climate scenarios. Integration of these data sets in applications brings the latest science to support the needs of SERVIR hubs and their end users.

7. SERVIR Applied Sciences Team and small grants

Through SERVIR, NASA's Earth Science Division's Applied Sciences Program advances the use of space-based observations to inform policy and decision makers as they adapt to the impacts of global change and plan for a sustainable future. NASA brings innovative and appropriate applied science to meet SERVIR user needs through the **Applied Sciences Team** (AST) as collaborating scientists. Proposals are competitively selected for three-year efforts to collaborate with hubs on SERVIR applied research activities. Through these activities, U.S.-based researchers are working with hubs, helping to bring the latest in Earth observation and geospatial technologies to bear on regional issues related to the SERVIR thematic areas. Developed in collaboration with the SERVIR hubs—who serve as co-investigators on the research--these projects are also designed to build regional capacity for using cutting edge tools and data. A complete list of past and current projects can be found here: http://www.servirglobal.net/SERVIR-AST .

As demand grows for geospatial tools and services, SERVIR connects with a broad range of institutions through its **small grants** program, which is coordinated by the SERVIR Support Team. Small grants, which are executed in SERVIR regions, encourage innovation by building partnerships with a wide range of organizations that are using Earth observations to solve national, regional, and local development challenges. Grantee institutions include non-governmental organizations, universities, and local government entities in SERVIR's regions. To increase public access to information, products and services developed through the small grants program are integrated into SERVIR's product Catalogue, and data layers generated by grantees are integrated into SERVIR's data catalogue.

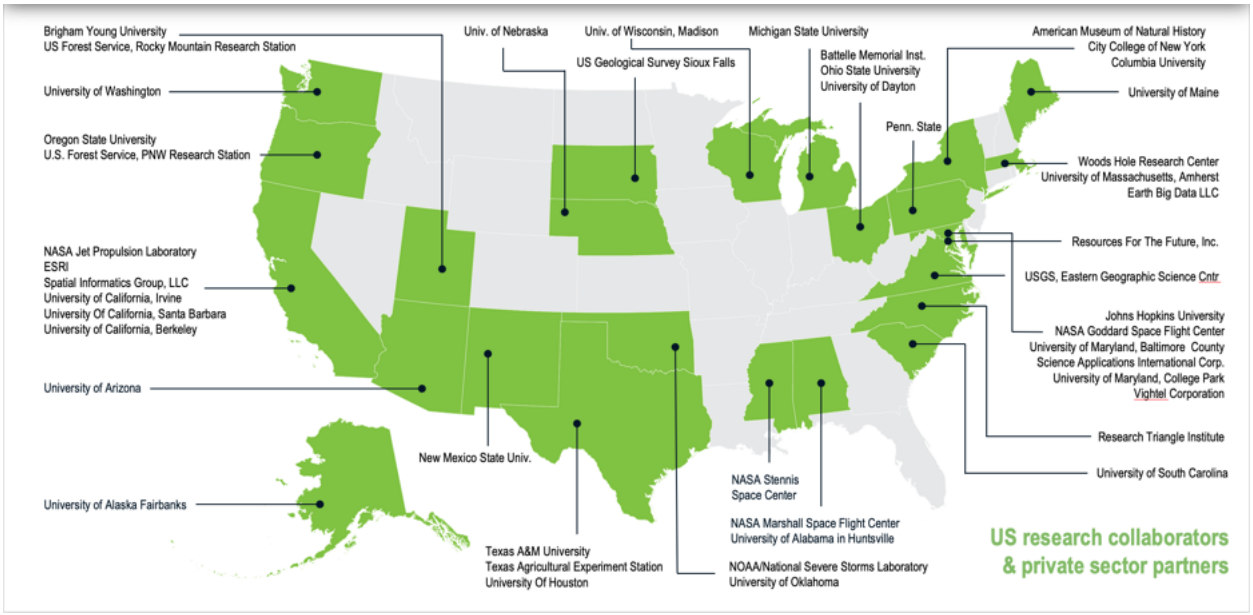

Fig. 4. AST Research Institutions collaborating with SERVIR across the United States

In 2015, the SERVIR program initiated a **Service Planning** approach to ensure that its services help developing countries effectively solve challenges related to agriculture, water management, land use, disaster management, and weather. Building on a wealth of past experiences in developing this new approach this Service Planning Toolkit is a resource for SERVIR hubs as they, with their partners, strive to make an impact in designing, delivering and implementing services. The Toolkit comprises four tools linked to the lifecycle of SERVIR services. They are 1) Consultation and Needs Assessment, 2) Service Design, 3) Stakeholder

Mapping, and 4) Monitoring, Evaluation and Learning. The Toolkit is based primarily on hub experiences with early elements of service planning. In addition, USAID, NASA and the hubs actively contributed to its development during the 2017 SERVIR Service Planning Exchange and the 2016 SERVIR Annual Global Exchange. This spirit of consultation and collaboration will continue as the SERVIR service planning approach evolves and the tools are refined. Intended as a living document, this Toolkit will be revised and improved periodically to reflect best practices across the SERVIR network. As noted earlier, this Toolkit embodies a new approach, which will evolve and grow over time.

The SERVIR Global Service Catalogue provides a one stop shop of all the SERVIR current services. It is a searchable collection of demand-driven geospatial services that use Earth observations to support decision making and resilient development in the four SERVIR Thematic Areas. SERVIR has 42 custom services in development or delivery stages. The services are categorized by region, service area, and data source. The list of current services can be found on the catalogue website.

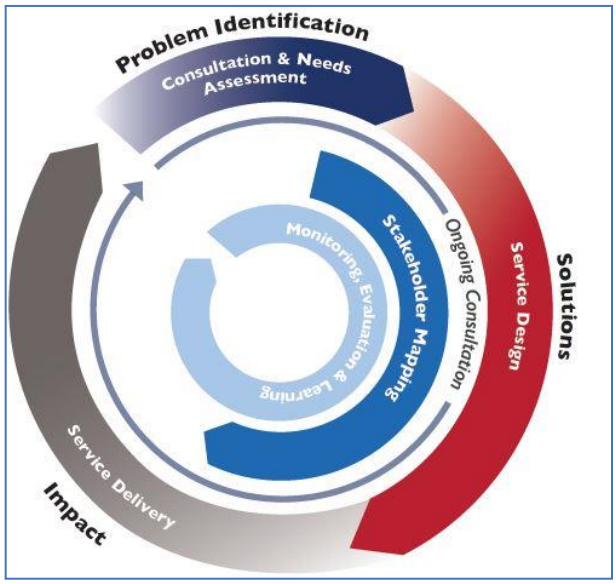

Fig. 4. Diagram representing the Service Planning Lifecycle

8. Global Exchanges

SERVIR's greatest asset is its people. Together, SERVIR's experts create a collaborative global network focused on some of the world's greatest challenges. Each year, the SERVIR network convenes multiple face-to-face exchanges. These exchanges play a pivotal role in strengthening the SERVIR Community of Practice by providing a venue for participants to share new ideas, methods, and lessons that can be implemented in the respective SERVIR regions.

Furthermore, exchanges help to create professional and personal contacts across the network so that all SERVIR members can see themselves as part of a larger global community. Exchanges are organized throughout the year covering a wide range of topics—from highly technical science-related themes to program management themes—based on the changing needs of the network. The **SERVIR Annual Global Exchange** (SAGE) is the program's premier event, drawing approximately 100 participants from around the globe representing SERVIR hubs; the SERVIR Science Coordination Office in Huntsville, Alabama; NASA HQ and USAID HQ in Washington, D.C., the SERVIR Support Team; and collaborating U.S.-based researchers, with members from across the United States. SAGE is designed to catalyze strong working relationships across the global network, support collaboration around work plans based on strong science, facilitate collective learning and exchange about improving program management, and foster practical approaches to ensuring the impact and sustainability of all SERVIR services and applications. During this week-long gathering, attendees have the opportunity to share best practices and discuss current Earth observation-related technical innovations, as well as best practices for service design and delivery. Other technical exchanges and workshops are conducted as needs arise, such as Geospatial Information Technology (GIT) Exchanges and Communication Exchanges.

9. Conclusions

Moving forward, SERVIR will continue to build on the significant achievements of the past decade and a half by increasing the use and impact of SERVIR tools and services, creating new connections across the network through training and workshops, forging new cooperative agreements with strategic partners, and focusing on sustainability at multiple levels. SERVIR's overarching goal is to improve environmental management and resilience in developing countries through the increased use of Earth observation information and geospatial technologies in decision-making. Four strategic goals guide the project through 2020: 1) Reach more users with demand-driven products and services: Since its inception, SERVIR has reached thousands of users in over 50 countries with more than 70 products, tools and services. There is now a strong opportunity to reach even greater numbers through scaling-up existing products to reach more end users, and increasing awareness of SERVIR services among broader audiences through improved communications and outreach 2) Connect more innovative and appropriate science to SERVIR: SERVIR will apply

new satellite data sources as they become available and engage with a greater variety of science and technology partners in the regions to take advantage of complementary research and analysis. This is being done through stronger linkages with regional programs, NASA-supported scientists and centers, plus providing access to a wider availability of free and open global data for the development of new products and services. 3) Expand SERVIR networks through new strategic partnerships: While seeking to deepen existing partnerships, SERVIR is pursuing new strategic partnerships, particularly with non-governmental organizations, private sector, academia and scientific communities. 4) Improve sustainability of SERVIR at multiple levels: Strengthening the sustainability of the SERVIR global network will be achieved through more active engagement with USAID Missions and global, regional, and bilateral programs to strengthen awareness and diversify support for the program. Hub-to-hub and global network exchanges will also be increased to sustain network relationships and facilitate knowledge and tool transfers to other regions with similar needs. Improving sustainability will also bring focus to the hubs' capacity needs, including science and technology, infrastructure, communication and learning, and management and financial resources.

With new tools in development, innovative partnerships, cutting-edge science and an expanding network of hubs, SERVIR looks forward to increasing the use of Earth observing data to help more people in developing countries adapt to a changing environment by connecting space to village.

Acknowledgements

The authors want to thank and acknowledge the entire SERVIR Global team and the tremendous work that they do to use Earth observation data to make an impact around the world for resiliency and prosperity. The SCO team in Huntsville, USAID team in Washington D.C., SERVIR Support Team, the Applied Science Teams, and the 5 SERVIR hubs provide the structure that allows us to apply science and build capacity around the world. Without their tireless efforts, this paper and this project would not have been possible.

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Table 1. SERVIR Satellites/Sensors and their applications

Satellites/Sensors	Application
ALOS (Japan) (PALSAR data)*	Vegetation structure
AltiKa (France, India)	Water and sea surface height
AMSR-E on Aqua* (NASA)	Soil moisture
Sentinel-1 and -2 (Europe)	Disaster response, vegetation
Terra-ASTER (NASA)	Vegetation properties, surface temperature and elevation
Digital Globe constellation** (USA)	High-resolution visible imagery
EO-1 30-m multi-spectral* (NASA)	Disaster response, vegetation change
GOES-16 (NOAA/NASA)	Atmosphere composition, cloud formation, air mass characteristics
GPM (NASA/Japan)	Precipitation
GRACE* (NASA/Germany)	Groundwater
ICESat (GLAS)* (NASA)	Land topography
Jason-2 and -3 (NASA/NOAA/France/Europe)	Water and sea surface height
LANDSAT 5*, 7, and 8 (NASA/USGS)	Vegetation properties, agriculture and land cover changes
Meteosat (Europe)	Atmospheric composition, cloud formation, air mass characteristics
QuikSCAT* (NASA)	Vegetation structure
Radarsat-2 (Canada)	Vegetation, surface water
SMOS (Europe)	Soil moisture and ocean salinity
SRTM (NASA)	Land topography
Terra and Aqua-MODIS	Land surface temp
TRMM* (NASA/Japan)	Precipitation
SMAP (NASA)	Soil moisture
VIIRS on Suomi-NPP (NASA/NOAA/DoD)	Land surface temperatures, vegetation, water resources, fire, light at night

* Satellite/sensor no longer producing data
** 5 Commercial Satellites in use through a unique data collection tasking agreement
Note: U.S.-affliated satellites and sensors are bolded