EVALUATION

SERVIR Performance Evaluation: Evaluation Question 1 Report

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Cover photo: Monsoon downpour in the Terai, Nepal

Credit: Jared Berenter, dTS

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ACRONYMS

CONAMAR	*Comisión Nacional de la Marea Roja* (National Red Tide Commission)
CREST	Coupled Routing and Excess Storage Tool
dTS	Development and Training Services
E3	Bureau for Economic Growth, Education, and Environment (USAID)
FFWC	Flood Forecasting and Warning Center (Bangladesh)
GHG	Greenhouse Gas
ICIMOD	International Center for Integrated Mountain Development
MSI	Management Systems International
NASA	National Aeronautics and Space Administration
NGO	Non-Governmental Organization
RCMRD	Regional Center for Mapping of Resources for Development
REDD+	Reducing Emissions from Deforestation and Forest Degradation Plus
SIGMA	Geospatial Information System for Fire Management
UNFCCC	United Nations Framework Convention on Climate Change
USAID	United States Agency for International Development

INTRODUCTION

This report provides summary findings, conclusions, and recommendations for the first of three evaluation questions for a midterm performance evaluation of the SERVIR program. Specifically, this report addresses the following evaluation questions:

> 1.a. Are SERVIR's products and applications being used in decision-making contexts? How (1) for hydrology (floods, etc.); (2) for land use, biodiversity and ecosystems; and (3) for disasters (fires, droughts, frost, etc.)?

> 1.b. What are the measurable impacts, both intended and unintended, of SERVIR's products and applications on the relevant societal benefit areas themselves in the countries where we work?

The Office of Global Climate Change in the United States Agency for International Development's (USAID's) Bureau for Economic Growth, Education, and Environment (E3) commissioned the E3 Analytics and Evaluation Project[1] to conduct the evaluation, which was designed and implemented between 2014 and 2017. USAID/E3/GCC commissioned the evaluation to better understand the use, impact, and value of SERVIR's tools, data, and capacity-building efforts for its user and beneficiary communities.

BACKGROUND

SERVIR Program

Named for the Spanish word meaning "to serve," SERVIR is a joint development initiative of the National Aeronautics and Space Administration (NASA) and USAID. SERVIR works in partnership with leading regional organizations around the globe to provide satellite-based Earth observation data and science applications to help developing nations improve disaster risk management and environmental decision-making.

SERVIR aims to improve environmental management and resilience to the impacts of climate change by developing the capacity of government agencies, non-governmental organizations, and other key stakeholders to use and integrate geospatial information and technology into their decision-making processes. Under this partnership, USAID and NASA have established SERVIR regional hubs in Central America, Eastern and Southern Africa, the Himalayas, and, most recently, Southeast Asia and West Africa. These hubs, in conjunction with dozens of participating governments and other institutions, develop and disseminate geospatial products and data to assist with regional, national, and local challenges related to disaster management, water resources, land-cover change, agriculture, biodiversity, and climate change.

Evaluation Design

This report presents findings of a cross-case analysis of nine case studies of SERVIR products in selected countries conducted by the evaluation team (see Table 1). Based on consultations with SERVIR team

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[1] Management Systems International (MSI) implements the E3 Analytics and Evaluation Project in partnership with Development and Training Services and NORC at the University of Chicago.

members from USAID and NASA, the evaluation team identified five areas of interest to SERVIR for review within the context of evaluation question 1:

1. Understanding product effects and impacts;
2. SERVIR product adoption and use;
3. Rapid-onset disasters and disaster response networks;
4. SERVIR product data in the broader development landscape; and
5. Identification and support of unexpected and evolving forms of product usage.

These five areas are used to structure this report.

TABLE 1: PRODUCTS SELECTED AS CASE STUDIES

Product Name	Case Study Designation
Ocean Algal Bloom Monitoring[2] for Mesoamerica	El Salvador ●●
Water-Quality Monitoring for Lake Atitlán, Guatemala	Guatemala 1 ●●●
SIGMA-1 Forest Fire Monitoring Suite in Guatemala	Guatemala 2 ●●
Rapid Response Mapping for Disasters	Nepal 1 ●
Agricultural Monitoring for Food Security in Nepal	Nepal 2 ●
Jason-2 Satellite Altimetry Flood Forecasting for Bangladesh	Bangladesh ●●
Coupled Routing and Excess Storage Tool (CREST) Hydrological Suite	Kenya ●●
Land-Cover Mapping for Greenhouse Gas (GHG) Emissions Inventory in Zambia	Zambia ●
Land-Cover Mapping for GHG Emissions Inventory in Rwanda	Rwanda ●

● Land use, biodiversity, and ecosystems products   ● Disaster-linked products   ● Hydrology products

The products the evaluation team examined in the nine case studies came from SERVIR's extensive catalog[3] of geospatial tools, maps, and products. The selection of case studies ensured a diverse range of geographic and sectoral coverage. The evaluation team conducted three case studies in each of SERVIR's three initial hub regions: Central America, Eastern and Southern Africa, and the Hindu-Kush Himalayas. The team also selected case studies with the expectation that each product under review would be in completed form, accessible to intended users, and active or available long enough to have produced an impact in its sector (e.g., a flood-mapping tool needed to be available for at least one entire flood season). When selecting products for case study research, the evaluation team chose to focus on products that had been available to users for at least a full year prior to its field visits to minimize the degree of a product's novelty limiting expected usage.

Additionally, per SERVIR's request, the evaluation team selected products with relevance across three societal benefit areas: (1) hydrology; (2) land use, biodiversity, and ecosystems; and (3) disasters. Table 1 lists the products selected as case studies, along with their abbreviated case study designation. Because considerable overlap occurs between societal benefit areas, products often fall into more than one category (e.g., streamflow monitoring fits within land use, disasters, and hydrology).

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[2] Also referred to as "red tide monitoring."
[3] At the time of SERVIR product and location selection for case study review, the initial pool included more than 40 products listed in the SERVIR catalog, as well as several additional products that were documented in other SERVIR literature. As of the writing of this report, that number exceeds 70.

UNDERSTANDING SERVIR PRODUCT EFFECTS AND IMPACTS

The case study approach allowed the evaluation team to identify how each selected product affected its users and beneficiary groups. The evaluation team saw signs of products' effects in three broad categories: environmental, economic, and social well-being (see Table 2). While not every product produced verifiable impact across all three areas, many products demonstrate a potential for future impact. This may be because a product is still relatively new (e.g., Nepal agricultural monitoring), because impact is pending due to a capacity gap (e.g., Kenya flood forecasting), or because a product is impeded by other factors affecting use (e.g., Rwanda land-cover mapping).[4]

TABLE 2: AREAS OF PRODUCT IMPACT

Environmental	Economic	Social Well-Being
• Ecosystem damages and losses averted • Preservation or restoration of threatened ecosystems • Carbon sequestration/ • reduced GHG emissions	• Changes in market confidence • Property damages and losses averted • Improved efficiency of service delivery • Access to donor funding	• Community sensitization/shifts in community behavior • Preservation of cultural and environmental heritage • Improved service delivery • Improved infrastructure • Improved community health • Lives saved

This study uses the term "impacts" to refer to results that flow from specific interventions. The study used techniques that are considered among the most effective for studies involving small sample populations.[5] Further, the team systematically sought information on other possible causes for the results it found, including other sources of geospatial information organizations may have used instead of or in addition to SERVIR information.

In certain cases, impact can be directly attributed to the SERVIR product. Attribution is clear, for example, when behavioral change occurs from product use. In Lake Atitlán, Guatemala, SERVIR maps provided visuals of an environmental threat in an accessible way. This transformed public opinion of the status of pollutants in the lake and drove direct measures in response. Clear attribution is also confirmed in situations where action was based exclusively on product information. This is the case in Petén, Guatemala, where first responders are regularly deployed based on information that comes directly from SERVIR hotspot maps.

In most cases, however, action and impact cannot be attributed exclusively to product use. Instead, SERVIR data play a contributing role in generating impact by increasing data confidence, filling a data gap, complementing other information, or enabling more efficient and targeted use of resources for data collection as part of a larger decision-making system. For example, SERVIR's daily algae bloom maps in El Salvador supplement on-the-ground testing of water and shellfish tissue samples, but subsequent action (i.e., a ban on shellfish consumption) is specifically based on the tissue sample findings, not the satellite imagery. Alternatively, a product may contribute to a knowledge base that informs the design or site selection of a program that, in turn, yields measurable impacts. In Nepal, the agricultural monitoring tool

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[4] The next section provides further discussion of factors influencing product use.

[5] For further information on small population approaches for determining impact, see Howard White and Daniel Phillips, "Addressing Attribution of Cause and Effect in Small *n* Impact Evaluations: Towards an Integrated Framework." 3ie Working Paper 15 (2012).

is one of many indicators of food insecurity and is thus a contributor to – but not the sole determinant of – food assistance program targeting. In such cases, the product can be expected to increase the effectiveness of informed decisions but cannot assume sole credit for the impacts of those decisions. In many cases, a product's ultimate benefit may simply be one more input used for administrative benefit, contributing to informational or reporting purposes.

Such administrative gains, which accrue due to better access to data and improved capacity for using data in decision-making, are difficult or impossible to measure for several reasons. Not least is the fact that institutions often are not transparent about data gaps, data confidence, or shortcomings of alternative monitoring methods. Nonetheless, in the long term, improvement in administrative efficiency can reasonably be expected to facilitate service delivery and result in positive effects on the impact areas shown in Table 2. Each reviewed product, except CREST's incomplete forecasting component, can be credited with some degree of administrative benefit.

Environmental Impact Areas

Across the nine case studies, the evaluation team identified three types of environmental impact supported by use of SERVIR's products and services: ecosystem damages or losses averted, threatened ecosystems improved or protected, and successful carbon sequestration. For the first two, impact can be measured in terms of the value of the ecosystem services or resources. For the third, impact would be measured as the stored value of carbon in terms of net carbon sequestered, if not also the expected monetary value of that carbon.

- *Ecosystem damages and losses averted:* In four of the nine cases, SERVIR products contributed to the prevention or mitigation of ecosystem damage by alerting decision-makers to environmental hazards or disasters. The hazard or disaster may have a slow or rapid onset.[6] In some cases, it extended the window of opportunity to take mitigating actions; in others, the alert spurred action that may not have taken place without use of the tool. This was most evident in Guatemala, where SERVIR products alerted or continue to alert decision-makers to environmental threats in two contexts.
- *Preservation or restoration of threatened ecosystems:* The evaluation team witnessed this directly in the two cases of land-cover mapping. In Zambia's North-Western Province, land-cover maps were used to select sites for reforestation activity. In both Zambia and Rwanda, these land-cover maps, which also serve as GHG emissions inventory baselines, are positioned to inform implementation of protection, afforestation, or reforestation as needed.
- *Carbon sequestration:* This impact occurs in the three cases where products affected forestry and natural resource management decisions. In Guatemala, Zambia, and Rwanda, SERVIR products were an information resource for decision-makers working to reduce long-run carbon emissions in the forestry sector. Given the limited activities that are formally connected to carbon sequestration and product-informed reforestation activities in Zambia and Rwanda, this impact is seen most clearly in Guatemala, where forest-based carbon stocks were protected through the use of SERVIR's forest fire management tools.

Annex C outlines areas of likely environmental impact across the nine case studies. The inventory suggests that consistent environmental impact is strongest in the forestry sector and/or where land-cover mapping is occurring, except for the one-off product in Lake Atitlán. The hydrological products

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[6] The next section provides further discussion on slow- and rapid-onset disasters.

and those meant for disaster response outside the forestry sector have not had observable or verifiable environmental impact.

Economic Impact Areas

Across the nine case studies, the evaluation team identified four types of economic impact that are fully or partially attributable to use of SERVIR's products and services. These include changes in market confidence; mitigation of property damages and/or losses; increases in efficiency of service delivery; and increased access to donor funds.

- *Market confidence:* SERVIR's two water-quality monitoring tools used in El Salvador and Guatemala were developed in response to algal blooms. This problem has significant negative economic repercussions for these countries' seafood and tourism sectors, respectively. For this reason, the short-term results of satellite detection of algal blooms can have a negative effect on the market, but in the longer term, increased effectiveness of monitoring appears to strengthen market confidence. This was particularly evident in El Salvador, where SERVIR satellite imagery is fully integrated into the monitoring system of the National Red Tide Commission (CONAMAR, the Spanish acronym for *Comisión Nacional de la Marea Roja*); seafood vendors and consumers consistently expressed their trust in and willingness to abide by CONAMAR's seafood consumption bans during serious red tide events. Improved market confidence also reportedly occurred in Kenya, where the CREST hydrological modeling tool has informed economic viability assessments for infrastructure projects.
- *Property damages and losses averted:* The case where economic damages and losses have been most clearly averted due to product use is in Guatemala, where SERVIR-informed forest fire risk modeling and hotspot mapping has facilitated more effective forest fire management and response, protecting a source of income and livelihood. The evaluation team also saw some limited indications of property damages and/or losses averted from product use for Jason-2 in Bangladesh and CREST streamflow monitoring in Kenya. These tools provide streamflow information to guide irrigation planning and flood information to inform flood response, although results are preliminary as certain aspects of both tools are still being rolled out. In other cases, the products are largely used for response rather than prevention (e.g., Rapid Response Mapping in Nepal, which is helping to prioritize and target government and NGO efforts to respond to natural disasters and environmental threats).
- *Efficiency of service delivery:* Compared to other forms of impact, the evaluation team found SERVIR products were most likely to contribute to improved efficiency of service delivery by government ministries and other product users. In four cases – Rapid Response Mapping in Nepal, both forest fire and water-quality monitoring in Guatemala, and land-cover mapping in Zambia – SERVIR products have informed actors of locations where services are needed. In two other cases (agricultural monitoring in Nepal and Jason-2 flood forecasting in Bangladesh), improved service delivery is an anticipated impact, pending further progress in product development and dissemination.
- *Access to donor funds:* In five cases, SERVIR products have been or are used to mobilize donor funding. Maps of Lake Atitlán in Guatemala and Rapid Response Mapping in Nepal have already been included in fundraising appeals by local and international NGOs for this purpose. In Zambia and Rwanda, land-cover maps establish baseline deforestation rates that can facilitate future financing tied to REDD+ and other carbon-sequestration initiatives.

Social Well-Being Impact Areas

Recognizing that environmental and economic impacts have strong implications for social well-being, the evaluation team identified five general types of social impact that are fully or partially attributable to use of SERVIR's products and services. These include community sensitization and behavioral shifts, preservation of cultural and environmental heritage, improved service delivery, infrastructure development, and improved community health and lives saved. Annex D details these impacts.

- *Community Sensitization and Behavioral Shifts:* Three cases illustrated community sensitization and behavioral change. The sensitization effect was particularly forceful for both Guatemala case studies. However, the sustainability of behavioral shifts is largely a function of product integration and systems development that enables the continued flow of information to people. In Atitlán, where imagery of the lake's algal bloom galvanized public opinion in response to a single event, momentum toward improved community practices has waned over time. In Petén, on the other hand, satellite imagery is fully integrated in fire management systems and regularly used.
- *Preservation of Cultural and Environmental Heritage:* In three cases, the environmental resources that were protected or restored due to SERVIR product use contain explicitly recognized and significant cultural value. Lake Atitlán, forest fire-vulnerable Mayan heritage sites and cultural artifacts in Petén, and trees as national patrimony in Zambia all fit these criteria, and all benefited from actions taken based on SERVIR product data.
- *Improved Service Delivery:* Improved service delivery in this context refers to both the provision of new services and the general improvement of pre-existing services relative to what was available prior to introduction of the products. This occurred in four of the nine cases. In Atitlán, Guatemala, for example, public outcry in response to the algal bloom image led to regulatory and policy initiatives that were previously weak or nonexistent. In Petén, Guatemala, first responders now respond to fires that previously would have received no response due to non-detection. In Kenya, CREST streamflow monitoring data contribute to decision-making around water resource management, including issuance of water-use permits by the Water Resources Management Authority. In Nepal, the World Food Programme used Rapid Response Mapping inundation maps produced by SERVIR and its regional hub for the Hindu Kush-Himalaya region, the International Center for Integrated Mountain Development (ICIMOD), to identify districts most affected by seasonal flooding and target relief delivery.
- *Infrastructure Development:* In select cases, SERVIR product use contributed to infrastructure development. This occurred to some extent in Guatemala, where building fire roads and firebreaks has been based on needs assessments informed in part by the SIGMA-I fire management tools. In Western Kenya, CREST hydrological models informed repair and construction of flood-prevention dykes as part of the Water Security and Climate Resilience Project, which is funded by the World Bank and operates out of the Kenyan Ministry of Environment, Water, and Natural Resources.

SERVIR PRODUCT ADOPTION AND USE

By design, each reviewed product had experienced some use to be considered for the case studies. However, the extent of adoption and integration into decision-making systems varied substantially across products. Figure 1 presents a spectrum of varied uses, and Annex A provides a more detailed overview of individual product use levels and the distinctions among them. These stages do not represent a uniform process; rather, the points on the continuum signify varying degrees of incorporation into institutional processes, demonstrating that product use is not dependent on full

integration of the product into a decision-making system. Given the cost and effort involved in developing and disseminating the SERVIR products, however, it is reasonable to view full institutional adoption and sustained use of the SERVIR products as an ideal objective for most products, but not necessarily for one-off or pilot products.

FIGURE 1: DEGREES OF PRODUCT USE
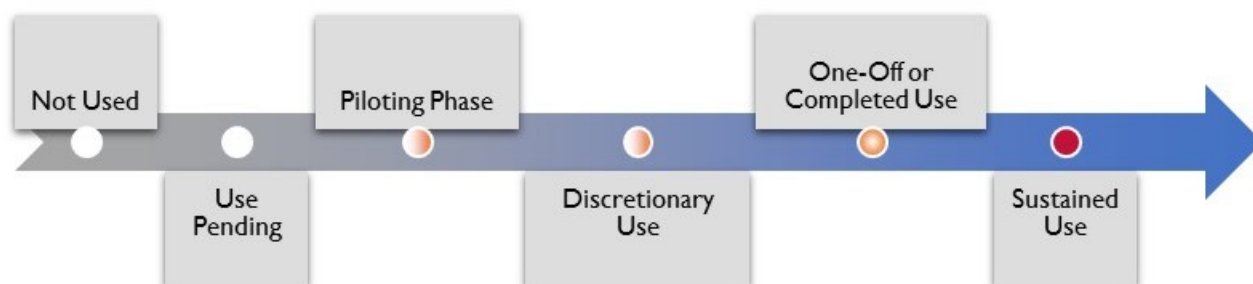
The evaluation team's conversations with members of SERVIR's product development and dissemination teams in the home office and at regional hubs made it clear that SERVIR has a long track record of success in conceiving, developing, and distributing utilitarian geospatial data products. A brief review of more than 70 products featured in SERVIR's online catalog further highlights the program's success in this area. However, many of these products have seen only limited use, and even those that are used frequently and extensively may achieve that only after several years of availability.

To better understand the institutional motivations surrounding the product adoption process, the evaluation team extensively interviewed in-country stakeholders from SERVIR clients currently using SERVIR products, as well as institutions and individuals who are likely to use them in the future.

In discussing reasons for use and non-use of geospatial technology in general and SERVIR products in particular, interviewees cited two types of motivating factors: product-related issues and institution-related issues. Interviewees cited predictable product-related issues such as higher resolution, faster data updates, broader coverage, greater accuracy, and more user-friendly interfaces. Institution-related issues were consistent in their priorities but less uniform, relating to institutional capacity, expenses, pre-existing policies, and even the presence of a broader community of practice.

Conclusions

None of these issues were particularly surprising. However, despite the variety of product adoption timelines and processes, these conversations suggest that SERVIR's product dissemination process can adapt to support and facilitate the product adoption processes that existing and future clients use. Attention to long-term product reliability appears to have a significant impact on both product- and institution-related issues. This extends beyond the dependability of the products' output data to also include confidence in the product's persistent availability and viability over time, and a broader level of trust in SERVIR as a continually engaged partner supporting the products.

For predictive products like CREST in Kenya and the Jason-2 flood forecasting tool in Bangladesh, client institutions in both countries emphasized the dangers of false positives, which are known to rapidly undermine trust in event forecasting. This concern regarding the consistent reliability of product outputs has delayed full rollout of the predictive component of CREST to ensure that the product meets the required data-quality standards. Similarly, although the Jason-2 flood prediction product is fully functional and available to the Bangladesh Flood Forecasting and Warning Center (FFWC), the center requires that it remain in "testing" status for four years before its outputs achieve official status for that institution. In

both cases, the adoption process has been much more protracted than expected, but clients remain committed to use the products once they meet internal standards.

Beyond the reliability of the product outputs, users also cited the importance of the product's availability over time. Institutions must have confidence in the longevity of an online product before committing to its adoption, lest they find themselves reliant on a product that becomes unavailable unexpectedly. This was seen in the success of the red tide monitoring system in El Salvador. One of the key factors in that product's continued use by El Salvador's CONAMAR is its consistent availability over several years. The product continues to be used despite the availability of two comparable tools. This daily provision of red tide monitoring data has been almost continuous since its introduction in 2005, a factor that its users cited as an important part of its persistent use as an integral part of their red tide monitoring system.

FIGURE 2: COMMUNITY RADIO STATIONS ARE A TRUSTED SOURCE FOR FLOOD WARNINGS IN THE PLAINS OF WESTERN KENYA.

In addition to keeping SERVIR products reliably available to client institutions, interviewees also spoke to the importance of SERVIR remaining readily available and responsive to issues surrounding the reliability and accuracy of its products. For example, in Zambia, errors on one of the GHG inventory maps limited their overall usability, but the issue was further complicated by a lack of clarity about who should be responsible for subsequent corrections to that map. Although SERVIR was supposed to be responsible only for the creation of the maps, along with some associated training and ground-truthing exercises, clients voiced concerns that SERVIR needed to be more engaged in the process of correcting the maps.

Table 3 summarizes the degree of institutional integration for the products the evaluation team examined.

PRODUCT CHAMPIONS

An additional factor for product adoption and use that deserves attention is the effect of a committed champion within the user institution. This was particularly evident in Guatemala, where each of the products reviewed in the case studies owed the greater part of their success to well-placed, high-ranking individuals who are committed to making sure that the outputs of the two respective products were used by the individuals under their authority.

In the case of the CREST products in Kenya, a key high-ranking ministry officer showed a similar level of commitment to the product's broader utility, even using it to provide informal guidance on infrastructure development and construction.

Recognizing a champion may not always be possible or appropriate. But these instances and other feedback from interviewees suggest the identification and facilitation of champions may, in some situations, provide the needed impetus to move a product from merely being available to being fully integrated into client practices.

TABLE 3: DEGREE OF INSTITUTIONAL INTEGRATION BY PRODUCT[7]

Degree of Product Use	Product	Intended or Expected Use[8]
Not used	Land-cover mapping for GHG inventory (Rwanda)●	Natural resource management
Use pending	CREST hydrological suite (Kenya)●●	Flood prediction
	Land-cover mapping for GHG emissions inventories (Zambia) ●	GHG inventory reporting
	Land-cover mapping for GHG emissions inventories (Rwanda)●	GHG inventory reporting
Discretionary use	CREST hydrological suite (Kenya)●●	Hydrological modeling
	CREST hydrological suite (Kenya)●●	Streamflow monitoring
	Land-cover mapping for GHG emissions inventory (Zambia)●	Natural resource management
	Rapid Response Mapping for disasters (Nepal)●	Disaster response
	Water-quality monitoring for Lake Atitlán (Guatemala)●●●	Monitoring harmful algae blooms
Piloting phase	Jason-2 flood forecasting (Bangladesh)●●	Flood prediction
One-off or completed use	Water-quality monitoring for Lake Atitlán (Guatemala)●●●	Visually communicating environmental information
Sustained use	Agricultural monitoring for food security (Nepal)●	Drought monitoring
	Oceanic red tide monitoring (El Salvador) ●●	Monitoring harmful algae blooms
	SIGMA-I forest fire management tools (Guatemala)●●	Forest fire monitoring/response
	SIGMA-I forest fire management tools (Guatemala)●●	Forest fire preparedness

● Land use, biodiversity, and ecosystems products   ● Disaster-linked products   ● Hydrology products

Observation and key informant interviews indicate that product development, testing, and rollout do not always appear to be synchronized between the SERVIR hub and the product recipient or user organization(s). A product that is perceived as ready for use by SERVIR may not yet be suitable for the intended user community, either due to the status of the product or the state of the user community. Despite positive interest in the SERVIR products across all the cases the evaluation team examined, the degree of the products' formal use was severely limited by local perceptions about product completeness. This was seen in differences of opinion regarding the viability and usefulness of the Jason-2 tool in Bangladesh, the land-use GHG inventory maps in Zambia, and CREST in Kenya. In Bangladesh, the product's in-testing status precluded the widespread dissemination of its data outputs. In Zambia, the flawed nature of the 2010 maps required more than a year of concerted collaborative effort before they could be used in conjunction with the 2,000 maps as a viable time-series dataset. In Kenya, despite interest from the disaster-response community in the CREST platform's predictive potential, the general attitude was to wait and see if its shortcomings were successfully addressed before taking any steps toward product use or adoption. The divergence between the SERVIR product release timeline and the client adoption timeline should not be regarded as a failure of dissemination, but rather an opportunity to continue trust-building with the product recipients.

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[7] All information here is based on three rounds of data collection conducted between October 2014 and June 2016. Some aspects are likely to have progressed since then.

[8] The report uses the term "intended" to capture specifically those principle uses the product developers had in mind, to distinguish them from the unexpected and/or alternative uses that are sometimes found for products after the fact. Unexpected and alternate uses are addressed later in this report.

Compliance with and deference to cautious adoption timelines is essential to establishing trust in the product. Furthermore, this provides an opportunity to continue improvement of the products themselves in cases where newer data can be incorporated into the existing datasets.

In fact, product "completeness" should not be conflated with the dissemination of a product but should be seen as a process that extends well into the product's functional lifetime. This gives SERVIR an expanded opportunity to build trust in the accuracy of the product's outputs and longevity, as well as the program's reliability as a provider, through the establishment of mutually agreed-upon reliability benchmarks early in the product development process. This ensures that the longer rollout process (and accompanying delays in product impact) can be accounted for or accelerated.

RAPID-ONSET DISASTERS AND ORGANIZATIONAL COMMUNICATION NETWORKS

The previous section discussed how in most cases where the SERVIR products are used, the primary product user or recipient of product data was not the primary decision-maker, and in many cases was not a decision-maker at all for the issue in question. In these cases, the exchange of the product data and how it moved from party to party was an essential part of how and why it was used. The evaluation team focused its field research activities on learning about information-sharing practices within the various respective sectors, both for SERVIR product-generated data and more generally.

To better understand how data move within and across institutional networks to reach the technical specialists who process and analyze the data, and the people who use the data for actionable decisions, the evaluation team mapped inter-organizational communication networks for both known and potential SERVIR product-using institutions. Although this mapping exercise was not equally insightful for all case studies, the evaluation team captured some elements of how inter-organizational networks affect the use of SERVIR data and products for decision-making. The mapping exercises sometimes produced communication snapshots that were too chaotic or too small and tightly connected to be insightful, but they suggested some important takeaways in select cases.

The evaluation team identified a distinction between data-sharing needs for slow-onset and rapid-onset disasters.[9] Slow-onset disasters (e.g., drought and hazardous algal blooms) generally take an extended time to produce emergency conditions and are normally accompanied by early warning signs. Similarly, chronic persistent conditions that exist even in the absence of shocks (e.g., deforestation and pollution), can contribute to or create slow-onset disasters. Conversely, rapid-onset events occur suddenly, with little or no warning and often with dramatic results (e.g., landslides, forest fires, and earthquakes).

Geospatial data, particularly when available near real-time, can be especially useful for informing responses to all these disaster types, but access to up-to-date information on rapidly changing ground conditions is more critical when responding to sudden or rapidly changing emergency situations. Since these types of events are often dynamic in their manifestations, it is vital that data outputs be delivered to the appropriate recipients in the shortest amount of time possible.

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[9] The definitions for the terms "rapid-onset disaster" and "slow-onset disaster" are based on the classifications commonly used by the United Nations' Office for the Coordination of Humanitarian Affairs and other disaster-response institutions.

In the case of slow-onset disasters, particularly when long-term indicators can provide advanced warning before dangerous conditions reach full strength, the necessary information can travel to the appropriate parties with less time sensitivity.

TABLE 4: SLOW- AND RAPID-ONSET PRODUCTS

Case Study Designation	Chronic/Slow-Onset Disasters	Rapid-Onset Disasters
El Salvador	Algal blooms	
Guatemala 1	Algal blooms, water pollution	
Guatemala 2		Forest fires
Kenya	Drought	Floods
Zambia	Deforestation, land-use change[10]	
Rwanda	Deforestation, land-use change	
Nepal 1		Floods, landslides, earthquakes
Nepal 2	Drought	
Bangladesh		Floods

Conclusions

As Table 4 indicates, the evaluation team identified application of SERVIR products and product data for rapid-onset disasters in four of the nine cases. In these cases, integration of SERVIR data into existing inter-organizational data-sharing and collaborative networks is even more critical to ensure the utility of a product's outputs. In the case of floods or forest fires, getting information to potential users means faster and more accurate response activity, which saves money, resources, property, and even lives.

The importance of this distinction is tied to the availability of Earth observation data. Even when satellite outputs are generated quickly, they require direct entry into the dissemination chain. Products have the most immediate utility when integrated into an existing communications network prior to the incident in question, and when done so in a format that recipient community members can access and use.

This was particularly evident in Guatemala, where forest fire management authorities have an established and well-connected communications network for transmission of daily forest fire updates. The evaluation team observed seamless integration of the daily hotspot maps into these authorities' forest fire management systems, and recently, actors within the forest fire network have expanded communications capabilities by transmitting hotspot maps and other pertinent information via the WhatsApp messaging system. This can increase access to the messaging for those who do not have immediate access to conventional email or Internet in rural Guatemala.

Bangladesh has a well-established similar flood warning infrastructure that is continually being upgraded and expanded. Although the country's Jason-2 Satellite Altimetry Flood Forecasting tool is in a trial status, it is positioned well for expanded usage by the FFWC, the central node for tracking and disseminating flood data. This is particularly evident in the communications network map in Annex C, which shows existing and potential information flows in Bangladesh's flood warning communications network at the time of the evaluation fieldwork.

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[10] Although "land-use change" is not synonymous with "disaster," many activities related to land-use change can carry negative environmental consequences, such as unplanned or uncontrolled urban growth, human encroachment on vulnerable environments, and the conversion of natural habitats to cropland.

In the case of Rapid Response Mapping data distributed in response to two recent natural disasters related to floods and landslides in Nepal, the evaluation team found that multiple parallel and overlapping networks for disaster information sharing exist, but access points, connectivity, and ability to receive and share geospatial capabilities vary widely. For example, Nepal's National Emergency Operations Center, headed by the Ministry of Home Affairs, is formally the central hub for communication and coordination of government institutions during disasters. The maps suggest that information shared through that network travels better to government agencies than to the non-governmental organizations (NGOs) also involved in disaster response.
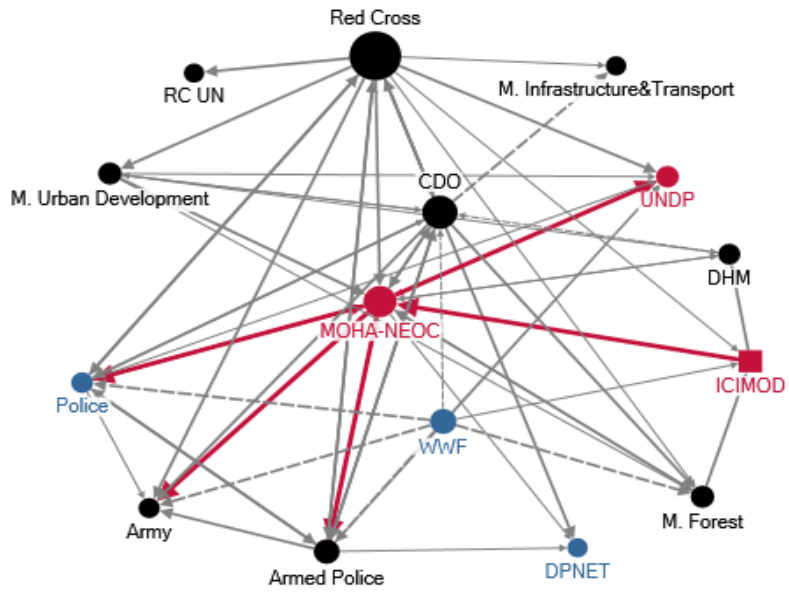
FIGURE 3: DISASTER-RESPONSE COMMUNICATION AND COLLABORATION NETWORKS IN NEPAL. THE SIZE OF THE NODE REFLECTS THE FREQUENCY WITH WHICH AN ORGANIZATION IS CITED AS A COMMUNICATIONS PARTNER. RED ARROWS INDICATE TRANSMISSION PATHWAYS OF SERVIR RRM DATA.

The network map generated from these exercises (Figure 3) suggests that the Nepal Red Cross may have been better positioned than the Ministry of Home Affairs to distribute the Rapid Response Mapping data to a wider range of disaster-response organizations. This has implications for how SERVIR selects and engages with clients initially, as well as how the program adds new clients.

Additionally, many disaster-response organizations in Nepal lack the technical capacity (skills or equipment) to use sophisticated computer software and may not be able to access large files via the Internet due to unreliable or slow connections. Interviewees from disaster-response organizations in Bangladesh and Kenya saw similar concerns over data sharing through intermediary organizations.

Despite this, interviews with people in areas that are vulnerable to flooding and forest fires made it clear that local communities are both attentive and responsive to reliable early warning systems, but the data must reach them in a clear and comprehensible fashion.

DEMONSTRATING OWNERSHIP – EVOLVING BEYOND BASIC PRODUCT USE

Some products indicated a usage level beyond "sustained use." In select cases, the principal user institutions had not only used the products but adapted or augmented their product usage in ways that suggest implicit "ownership" of the products.

The most striking example was in Guatemala. SIGMA-1 forest fire monitoring data was used broadly by actors working in the forest management and protection sectors, but also in hard-to-reach areas. This was done through data transmission with the WhatsApp phone application, which enables instant transmission of electronic data files to people who do not have easy access to conventional email or Internet. This includes first responders and community leaders in isolated rural areas.

Recommendations

Because inter-organizational network connectivity is so essential for speedy sharing of information during rapid-onset disasters, SERVIR and its hubs should tailor the data product with the full dissemination network in mind, and not just the next chain in the network. This includes identifying additional partners for whom product outputs may be useful in a disaster situation.

A more extensive understanding of the existing communication and collaboration networks will bring increased connectivity as well as new opportunities for pre-emptively building capacity prior to rapid-onset disasters. A wider range of organizations can then be primed to deliver electronic geospatial data or have the opportunity to request that data in whatever formats are most useful (e.g., printouts or thumb drives). This suggests that SERVIR and its hubs should prioritize assisting intermediary parties with providing or converting technical information into easily understood formats.

During emergencies, communication networks often shift into a more agile stance, changing their decision-making center of gravity to be closer to events on the ground. This may include alternate points of contact, modified chains of command, and redistribution of decision-making authority. Thus, in any future mapping of disaster-response communication networks by SERVIR or its hubs, they should attempt to capture both the conventional communication networks and the way they change during those disaster events.

SERVIR PRODUCT DATA IN THE BROADER DEVELOPMENT LANDSCAPE

Across the nine case studies, information generated by SERVIR consistently represented one component within a larger landscape of decision-influencing factors. Even in scenarios in which SERVIR products were generating or aggregating information that would have been unavailable otherwise – such as the SIGMA-1 forest fire hotspot mapping in Guatemala and CREST's nearly real-time streamflow calculations for entire Kenyan watersheds and river basins – other information had to be considered before making any final decision regarding response activity. Thus, a full examination of the use and effectiveness of the various SERVIR products requires a clear understanding of how data from the SERVIR products are combined with other information during the decision-making process, as well as what decisions can be made with that combined information.

Although this summary report does not provide a full exploration of the information environment for each of the nine case studies, even a brief review of some of those cases highlights the importance of understanding how the product data are or are not combined with related information sources (see Table 5).

TABLE 5: COMPLEMENTARY DATA SOURCES FOR SERVIR PRODUCTS

Product	Complementary Data Sources
El Salvador Algal Bloom Monitoring	Lab results from monthly water tests Lab results from monthly bivalve tissue samples
Guatemala Water-Quality Monitoring	Lab results from monthly water tests Inspection of sewage treatment facilities
Guatemala Forest Fire Monitoring	Local reporting on fire risk conditions Permit calendars for legal brush-burning
Kenya CREST Hydrological Suite	Meteorological forecasting data Community-based reporting to local radio stations In situ daily measurement of stream height
Zambia Land Cover Maps for GHG Emission Inventory	Zoning maps of jurisdictional authority Google Earth
Rwanda Land Cover Maps for GHG Emission Inventory	Official national orthophotographic[11] maps Land registration and zoning permit change data
Nepal Rapid Response Mapping	Aerial photographs of disaster sites Community-based early warning system[12] Reporting from district-level offices
Nepal Agricultural Monitoring	Digital agricultural atlas of Nepal[13] Reporting from district-level offices
Bangladesh Flood Forecasting	Upstream water height reporting from India In situ daily measurement of stream height

In the case of the algal bloom monitoring tool that is in use in El Salvador, daily SERVIR water temperature maps indicate an elevated likelihood of harmful algae bloom growth but do not on their own trigger a public alert regarding possible contamination of seafood by toxic bacteria. CONAMAR, the institution responsible for monitoring toxin levels, conducts regular water-quality tests and shellfish tissue sample tests at key coastal locations, which can trigger public warnings and seafood consumption moratoriums. The daily maps that SERVIR provides can alert CONAMAR of the need for increased testing in situations where a rapidly developing bloom may outpace the conventional testing schedule.

Similarly, the agricultural monitoring tool tracking potential instances of food insecurity in Nepal is most applicable in selecting locations for further investigation during the twice-yearly food-monitoring missions that the Ministry of Agriculture conducts for the World Food Programme. The vegetation index generated by the SERVIR agricultural monitoring tool is recognized as a viable metric for identifying and tracking food insecurity and is included in Nepal's quarterly food security bulletins. In addition, 16 other metrics are also included, including extensive reporting on field conditions from district offices.

In Rwanda, the SERVIR inventory maps will be used for GHG inventory reporting to the United Nations Framework Convention on Climate Change (UNFCCC), but they are unlikely to be formally used for any other purpose. Two country-specific factors have a heavy influence on the relevance and utility of the Land Cover Maps: geographic size and formal data-use practices that are consistent across administrative units. Extensive orthographic mapping of the entire country was conducted concurrently with the most recent satellite-derived land cover classification and mapping used for the Land Cover Maps and provides substantially higher levels of detail. These publicly available ortho-photographic maps are integral to

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[11] Orthophotographs are digital aerial photographs that have been edited to compensate for image distortions from factors such as camera tilt and geographic contour.

[12] Primarily used for flash floods.

[13] Generated by ICIMOD.

Rwanda's national planning, and although expensive to produce for an entire country, Rwanda's small size made them much more affordable than they might be for another country. Not only are the maps more detailed than satellite-derived imagery, they are recognized by all agencies within the Government of Rwanda as the official base maps for any formal government decision-making on national resource management, urban planning, agriculture, and other national planning. This precludes official use of the SERVIR Land Cover Maps for those purposes.

Conclusions

As the usability of products and their data is heavily determined by host country capacity at national, regional, and local levels, product usage is largely driven by the question of what is possible: What can people who are positioned to change conditions or outcomes on the ground realistically do with that data?

Cases like the SIGMA-1 forest fire monitoring tools in Guatemala and the algal bloom monitoring tool in El Salvador provide relatively straightforward opportunities for product-informed response. Knowing the location of a probable forest fire enables more effective and efficient targeting of limited resources during fire season. Similarly, although daily updates on the size and location of a growing algae bloom event do not enable bloom prevention, they facilitate increased testing and additional precautionary measures to ensure contaminated seafood is kept out of the commercial food chain.

In other cases, however, use of the data requires additional analytical steps to generate actionable information. In Zambia and Rwanda, the time series Land Cover Maps provide data on land use change that is critical to generating GHG inventories from land use change and forestry. These inventories are required for reporting to the UNFCCC, which was their intended use, but additional analysis and products are often needed to identify actions for managing land use. In their current form, the SERVIR-supported Land Cover Maps alone are insufficient to inform solutions for addressing deforestation and land degradation.

However, use of product data can be transformative. This was seen in both Guatemala's Atitlán community and in the flood-vulnerable rural regions of northern Bangladesh, as follows:

- In Atitlán, the imagery from SERVIR's water-quality monitoring is used as a regular reminder to the residents of the towns surrounding the lake that their daily actions have an impact on the health of the very same lake on which their livelihoods depend. Because the algae blooms are fed by organic pollutants entering the lake ecosystem (e.g., nitrogen and phosphorus from fertilizers, human waste, and detergents), community leaders and environmental organizations have incorporated the tool's images into sensitization activities focused on reducing these factors.
- In Bangladesh, where the flood early warning system window has only recently expanded from three days to five, the eight-day warning window provided by SERVIR's Jason-2 flood prediction system is part of a larger continual adaptation to the use of new information. Because the expanded forecasting window makes new adaptive strategies possible in the flood-vulnerable regions, the local communities are just beginning to adopt new methods for mitigating the harmful impacts of major flooding incidents. These include rapid construction of elevated structures to protect property and livestock from the rising floodwaters, and preemptive liquidation of perishable assets before disaster conditions reduce their market value.

Recommendations

Although SERVIR's product development teams certainly appear to have a clear idea of how the products can be useful, they are not always aware of the accompanying conditions and circumstances

where they hoped to see product use. To better understand and anticipate the ways in which SERVIR's products are used and how to expand that usage, SERVIR product development teams should incorporate theories of change into the product development process to assist with clear definitions of what "use" means for the client at both an administrative level and an end-user level. A more nuanced understanding of exactly what "use" means and entails will not only help manage expectations for situations where the potential for product-derived benefits may be limited, but it can also suggest new ways in which to modify or expand a product's utility beyond its initial conception.

UNEXPECTED AND ALTERNATIVE USES FOR SERVIR PRODUCTS

Each of the SERVIR products examined was developed with a defined set of uses and users in mind. This is evident from a review of the SERVIR catalog, as well as from conversations with key program staff. In the field, however, the evaluation team regularly encountered instances where actors from government institutions, universities, private industry, and NGOs and international NGOs were using products in interesting and sometimes unexpected ways.

TABLE 6: UNEXPECTED AND ALTERNATIVE USES FOR SERVIR PRODUCTS

Product	Unexpected/Alternative Uses
El Salvador algal bloom monitoring	Strengthening/correcting other data Preventing/Debunking false alarms Informing scientific/academic discussion
Guatemala water-quality monitoring	Strengthening/correcting other data Catalyzing public action Fundraising Informing scientific/academic discussion
Guatemala forest fire monitoring	Strengthening/correcting other data Discouraging illicit brush-burning
Kenya CREST hydrological suite	Strengthening/correcting other data Informing scientific/academic discussion Informing construction activity
Zambia GHG emission inventory	Informing reforestation REDD+ preparedness
Rwanda GHG emission inventory	Strengthening/correcting other data Informing scientific/academic discussion
Nepal Rapid Response Mapping	Informing scientific/academic discussion Fundraising
Nepal agricultural monitoring	Strengthening/correcting other data
Bangladesh flood forecasting	Strengthening/correcting other data

Strengthening/Correcting Data

Table 6 shows that the most common alternative uses were cases where the products or outputs strengthened or corrected weak, incomplete, or questionable data from other sources. Even where product use for decision-making was limited, in some instances the use of the product or its outputs complemented preexisting practices. The availability of a separate and reliable second or third data source allows users to assess the overall quality of the other data, fill in missing portions, and resolve or verify conflicting elements from multiple sources. Instances of data strengthening and correction include

- In Bangladesh and Kenya, hundreds of enumerators conduct conventional flood monitoring around the country and are responsible for taking daily stream-height measurements from a network of stream gauges (see Figure 4) near their homes or workplaces. Geospatial data offer free, global, regularly updated data that complements higher-resolution local data. Although SERVIR products are not as precise as physical measurements, they have verified or filled gaps in primary data collection methods when more conventional methods yielded unusual or incomplete readings.
- For the water-quality monitoring tool in Guatemala, the capture of satellite-based spectral analysis images was synchronized with physical in situ water sampling to enable more precise comparison of two types of water-quality testing methods to enable broader and more effective water-quality analysis.
- The incorporation of the SERVIR agricultural monitoring tool's data into Nepal's Food Security Monitoring System[14] added an additional layer of information to 16 other food security monitoring indicators being used in Nepal, increasing overall confidence in the final data outputs for quarterly agricultural reporting.
- In Rwanda, discrepancies between the SERVIR land-cover maps and similar maps led to a review and correction of an inaccurate agricultural land-use map that would have otherwise gone unnoticed by the Ministry of Agriculture.
- Forestry officials in Rwanda cited the SERVIR land-cover maps from 1990 and 2000 as resources for filling the historic data gaps from the Rwandan civil war, though they had not yet used them for that purpose.

FIGURE 4: A FARMER STANDS BY A RIVER GAUGE STATION ON THE DHARLA RIVER IN BANGLADESH, MAY 2015. *CREDIT: NIZAM AL-HUSSAYNI, DTS*

Other Uses

The evaluation team identified other types of alternative and unexpected uses that, although less consistent in their frequency, covered a range of uses as diverse as the tools themselves. These include:

- Individuals from the academic and scientific communities in Guatemala, El Salvador, Kenya, Rwanda, and Nepal using SERVIR product data in their research and teaching.
- Disaster-response and environmental NGOs using images and data generated by SERVIR products in their public appeals for funding in Guatemala and Nepal.
- The Zambian environmental ministry plans to use SERVIR GHG emissions inventory data for REDD+ planning and compliance.

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[14] The Nepal Food Security Monitoring System is a joint collaboration between the Nepal Ministry of Agriculture and the World Food Programme.

- CONAMAR in El Salvador using images from the SERVIR Oceanic Red Tide Monitoring product to debunk a false rumor of algae-contaminated seafood by showing the total absence of red tide/ harmful algae blooms in the area at the time.
- The Ministry of Environment in Guatemala using dramatic imagery from SERVIR's water-quality analysis to publicly show the severity of the environmental conditions in the Atitlán region. This was done to drive behavioral change among businesses and communities in that area.

Conclusions

The diversity of these alternative product-use cases points to the viability of applying the products outside their original intent. The evaluation team identified these cases of alternative and unexpected product use through an informant-driven snowball sampling[15] process that began with training attendees and workshop participants. These individuals were often not directly affiliated with the client institutions that worked closest with SERVIR for the product development and rollout process. Nonetheless, they were aware of the existence of these products, usually through participation in a training or workshop at a SERVIR regional hub, and they had taken the initiative to apply the tools to their own situations and circumstances. This highlights the role hub training and workshop sessions play in the dissemination of SERVIR products. It also underscores the importance of long-term relationship-building between SERVIR hubs and people who have attended classes, trainings, or workshops.

Recommendations

Given the many cases where SERVIR product users have, without prompting, incorporated components of the various products into their work, it is clear awareness of the products is an essential part of expanded product use. SERVIR and its regional hubs should seek ways to proactively support this, such as continuing to use their trainings and workshops to publicize and promote their full range of products and services to the diverse communities they serve. Furthermore, to be better apprised of the various unexpected or alternative applications of the SERVIR products, the program's hubs should expand the attention they give to their various sustained client relationships. This could take the form of expanded newsletter distribution highlighting new and upcoming products and their potential, increased visibility at national and international conferences (e.g., those related to hydrology, meteorology, natural resource management, and disaster response), blog-form or other analytical products, and engagement with or development of communities of practice within the geospatial communities in SERVIR's various member countries.

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[15] In snowball sampling, each interviewed stakeholder or individual is asked for referrals and contact information for other relevant stakeholders, either within their own organization or in connected organizations. Although this method can create bias in respondent selection, it can be a powerful tool for identifying and contacting a large number of potential stakeholders in a single connected network.

ANNEX A: DEGREE OF PRODUCT USE

Product Use	Product
Not used	**Land-Cover Mapping for Forest Management[16] (Rwanda):** Use of maps was redundant and unnecessary for this purpose in Rwanda due to previously established policy related to forestry, including an award-winning comprehensive national plan for reforestation and forest management, as well as the existence of higher-resolution official maps serving the same purpose.
Use pending	**Agricultural Monitoring for Food Security (Nepal):** These maps of district-level normalized-difference vegetation index anomalies stand to inform Nepal's Ministry of Agriculture Development's service delivery to food-insecure districts. **CREST Flood Forecasting (Kenya):** The forecasting component of the CREST hydrological modeling depends on the reliable delivery of accurate meteorological information by Kenya meteorological service. SERVIR and its Eastern and Southern Africa hub, the Regional Center for Mapping of Resources for Development (RCMRD), are working to improve that capacity, at which point some level of use by other local partners is likely. **Land-Cover Mapping for GHG Emissions Inventories (Zambia):** Once inaccuracies have been corrected, RCMRD land-cover maps in Zambia are set to be approved by the surveyor general at the Ministry of Lands and will serve as the country's land-cover baseline for REDD+ reporting.
Discretionary use	**Water-Quality Monitoring (Data) (Lake Atitlán, Guatemala):** Time-series data indicating algal concentrations in Lake Atitlán is available for individual or organizational use. The support value of this information was recognized by Guatemala's Lake Atitlán water authority, Authority for the Sustainable Management of the Lake Atitlán Basin and Its Surroundings and Let's Live Better (*Vivamos Mejor*), a prominent local NGO. **Rapid Response Mapping for Disasters (Nepal):** ICIMOD provides rapid-response maps on a case-by-case basis in response to natural disaster. Use of the maps is left to the discretion of the National Emergency Operations Center, headed by the Ministry of Home Affairs. **CREST Hydrological Modeling (Kenya):** Modeling of several flood-vulnerable basins has been conducted through collaboration between RCMRD and its partners and the Government of Kenya. Information based on this modeling has informed some infrastructure and construction projects. **CREST Streamflow Monitoring (Kenya):** Although not formally institutionalized by government agencies monitoring stream levels in Kenya, multiple institutions reported the use of this product for filling gaps left by their own monitoring practices and for double-checking their own collected data. This information informed decision-making related to water resource management. **Land-Cover Mapping for Forest Management[17] (Zambia):** Provincial officials in Zambia's North Western Province have used draft versions of the RCMRD land-cover maps to select sites for reforestation.
Piloting phase	**Jason-2 Flood Forecasting (Bangladesh):** The FFWC in Bangladesh is piloting the Jason-2 flood forecasting system; full adoption depends on verification of long-term product accuracy.

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[16] The stated purpose of the Land Cover Maps that were generated for Zambia and Rwanda was GHG emissions inventories, as stated in the product's formal title. Nonetheless, interviewed recipients consistently spoke of the tool as both a GHG inventory resource and as a forest management tool. Although this application of the Land-Cover Mapping for GHG Emissions Inventories is not explicit in any of SERVIR's own documentation, this consistent perception suggests that utility for forest management decision-making is implicit to the nature of the maps.
[17] Ibid.

Product Use	Product
One-off or completed use	**Water-Quality Monitoring (Imaging) (Lake Atitlán, Guatemala):** A map of chlorophyll concentrations in Lake Atitlán was publicly disseminated in response to a massive fresh-water algal bloom.
Sustained use	**Oceanic Red Tide Monitoring (El Salvador)**: As a matter of protocol, CONAMAR monitors daily maps of algal concentrations to detect algal blooms off the country's Pacific Coast. **Forest Fire Monitoring/Response (Guatemala)**: Guatemala's Center for Monitoring and Evaluation, part of the National Commission for Protected Areas, monitors and disseminates daily hotspot maps and weekly hotspot reports to assist first responders with locating and controlling forest fires. **SIGMA-I Forest Fire Management Tools:** Developed by the Center for Monitoring and Evaluation, the SIGMA-I tools inform planning decisions made by Guatemala's forest fire management network, the Forest Fire Prevention and Control System. **Agricultural Monitoring for Food Security (Nepal):** These maps of district-level normalized-difference vegetation index anomalies have been integrated into biannual crop-monitoring missions conducted by Nepal's Food Security Monitoring Network, led by the World Food Programme and the Ministry of Agriculture Development. **Land-Cover Mapping for GHG Emissions Inventories (Rwanda):** The Rwandan Ministry of Environment will use these map products as intended for its future GHG emissions inventory reporting to the UNFCCC.

ANNEX B: TYPES OF USE OBSERVED

PRE-ONSET: Monitoring, service delivery, and project implementation
1. Target high-priority areas or select sites for service delivery to mitigate the potential for natural disaster (Guatemala forest fire monitoring, Kenya CREST hydrologic modeling).
In two cases, stakeholders use or have used SERVIR products to target areas at high risk of disaster for service delivery to mitigate disaster risk. Guatemala's forest fire management network uses historical models of forest fire risk, developed in cooperation with SERVIR, to position material and human resources and early warning systems to prevent and reduce damage from forest fires. In Kenya, CREST flood-mapping models have been used as part of hydrological analyses to plan dyke construction in flood-prone areas in Western Kenya.
2. Assess feasibility or viability for project implementation (Zambia land-cover mapping).
Closely related to the previous example, in case studies where products are used in response to chronic environmental stress, respondents expressed interest in using SERVIR products to assess viability for project implementation. In Zambia, for example, private-sector respondents indicated that RCMRD land-cover maps may be useful in the future to determine viability for implementation of local REDD+ programs.

POST-ONSET: Response and service delivery
1. Target high-priority areas or select sites for service delivery to respond to natural disaster or environmental threat (Nepal Rapid Response Mapping, Nepal agricultural monitoring, Guatemala water-quality monitoring for Lake Atitlán, Guatemala SIGMA-I forest fire management products, Zambia land-cover mapping).
A common ground-level function of SERVIR tools is the identification of high-priority areas for service delivery site selection in response to the onset of a disaster. In Nepal, for example, rapid-response inundation maps allowed the World Food Programme to prioritize service delivery to highly affected areas in response to 2014 seasonal floods in Nepal's southern Terai region. The World Food Programme further hopes that maps of vegetation anomalies will inform service delivery in Nepal's agricultural sector. In Guatemala, a high-profile map of an algal bloom in Lake Atitlán spurred local and national stakeholders to implement regulatory and enforcement measures to prevent future outbreaks. Likewise, Guatemalan fire management authorities collaborated with SERVIR to identify fire scarring in the country's northern Petén region. Finally, in Zambia, provincial authorities in the country's North-Western Province have used RCMRD land-cover maps to target reforestation activity.
2. Galvanize public opinion and action in response to an environmental issue (Guatemala water-quality monitoring for Lake Atitlán).
A key source of value of SERVIR's algal bloom monitoring efforts in Guatemala is SERVIR's ability to present the magnitude and severity of an algal bloom in a visual manner. The SERVIR image produced in response to a 2009 algal bloom galvanized public opinion and action in response to contaminants entering the watershed.
3. Direct response/alert issued (Guatemala forest fire monitoring, Bangladesh Jason-2 flood forecasting).
The evaluation team witnessed two cases in which SERVIR products dictated direct response. Most prominently, in Guatemala, where authorities monitor hotspot activity daily during forest fire season, hotspot maps inform local first responders where fire activity is occurring. Response teams are dispatched to geographic coordinates identified by the product. In Bangladesh, the Jason-2 flood forecasting tool remains in a pilot phase, but on at least one occasion authorities have relied on it to issue a flood alert.

| POST-ONSET: Reporting |
|---|
| 1. Status reporting (Rwanda and Zambia land cover mapping). |
| In Rwanda and Zambia, RCMRD land-cover maps were completed as part of the countries' obligations to the UNFCCC to establish deforestation and GHG emissions baselines to further these countries' REDD+ readiness efforts. |

CONTINUOUS: Inform monitoring activity
1. Guide frequency and location of complementary monitoring tools (El Salvador red tide monitoring, Nepal agricultural monitoring).
The evaluation team observed two cases where the SERVIR tool guided and informed more comprehensive monitoring systems. As mentioned, daily maps of chlorophyll concentrations off the Pacific Coast in El Salvador inform more comprehensive monitoring decisions about when and where to test water and shellfish samples. Likewise, satellite-generated vegetation indices inform site selection for ground-level crop monitoring missions conducted biannually in various locations across Nepal.

ANNEX C: COMPARATIVE DISSEMINATION FLOWS FOR FLOOD FORECASTING DATA IN BANGLADESH
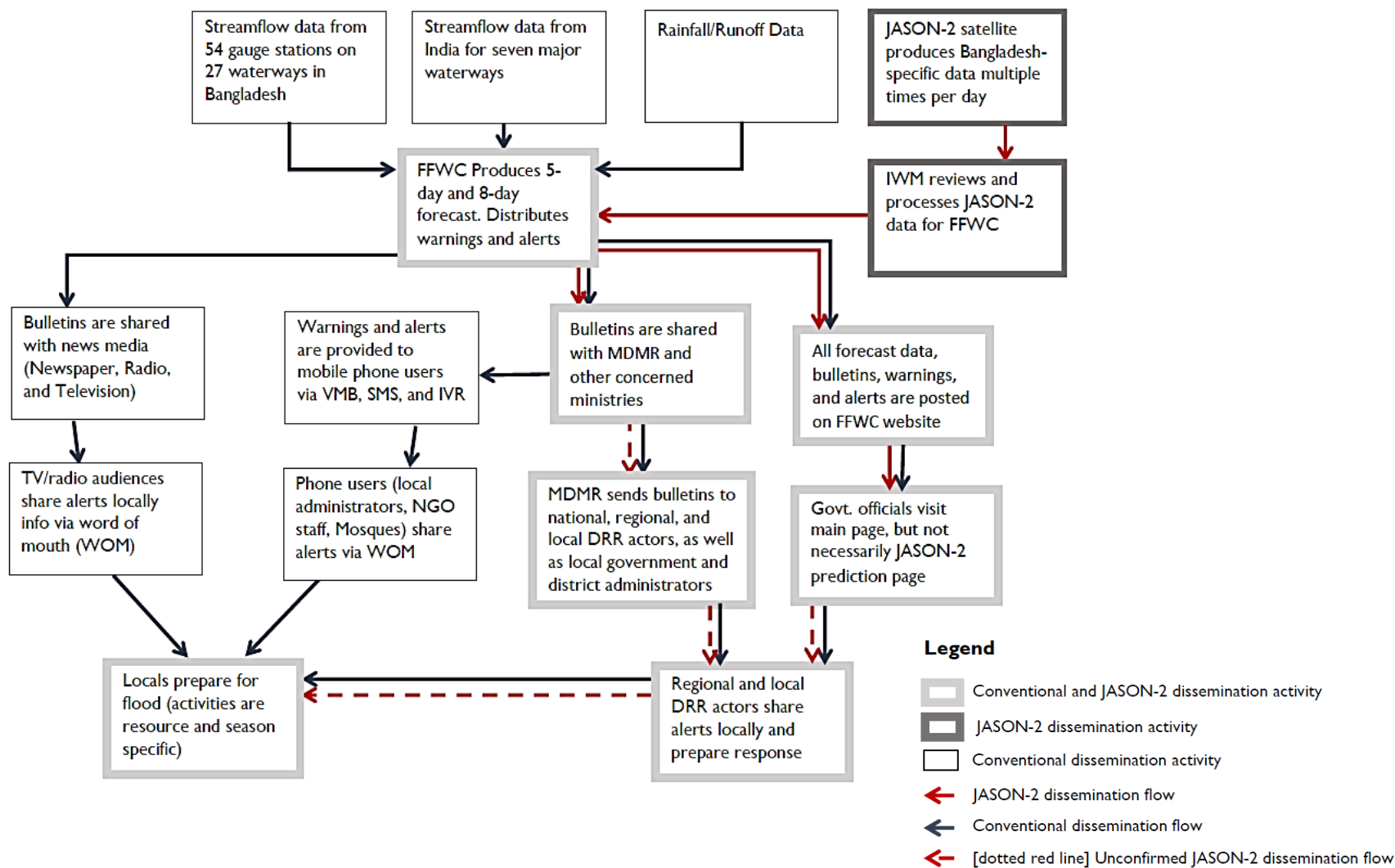
ANNEX D: PRODUCT IMPACTS

Case Study	Purpose	Economic Impact					Social Wellbeing Impact						Environmental Impact		
		Market confidence	Property damages and/or losses averted	Administrative efficiency	Efficiency of service delivery	Access to donor funds	Preserve cultural or environmental heritage	Improved community health	Community sensitization cultural shift	Lives saved	Improved service delivery	Provision of infrastructure	Ecosystem damages and/or losses averted	Delivery of ecosystem services	Carbon sequestration
El Salvador ●●	Oceanic Red Tide Monitoring	(+/-)	(-)					#		#					
Guatemala 1 ●●●	Water-Quality Monitoring (imaging)			■	■		■	#			■		■		
	Water-Quality Monitoring (data)			■	■		■		■		■		■		
Guatemala 2 ●●	Forest Fire Monitoring/ Response		■	■				■	■		■		■		■
	Forest Fire Preparedness		■	■				■	■		■		■		
Nepal 1 ●	Rapid Response Mapping		*	■	■					■	*	■			
Nepal 2 ●	Agricultural Monitoring				■	†									
Bangladesh ●●	Flood Forecasting				§				■		§				
Kenya ●●	Hydrological Modeling	■		■	■		■								
	Streamflow Monitoring			■	■						■				
	Flood Forecasting														
Zambia ●	UNFCCC Reporting/ REDD+			■		¥								¥	¥
	Forest Management			■					■				■	■	■
Rwanda ●	UNFCC Reporting/ REDD+			■		¥								¥	¥
	Forest Management			■											

* Data collection was completed before the April/May 2015 earthquakes thus the team could not assess property damages and/or losses averted and lives saved.

† Indications that the agricultural monitoring tool have or will be used for Feed the Future grants have yet to be confirmed.

§ Use confirmed because product's eight-day forecast information was included in an FFWC daily bulletin, but field team could not confirm impact.

¥ Product has been used for preparing UNFCC reporting; broader impact is anticipated but is yet to occur.

Health impacts cannot be measured due to weak reporting on health outcomes and uneven diagnosis of algae-caused illnesses, but harmful algae blooms can have fatal effects.