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EVALUATION

SERVIR Performance Evaluation: Evaluation Question 3 Report

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SERVIR Performance Evaluation: Evaluation Question 3 Report

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Prepared By:

Isaac Morrison, Management Systems International (MSI)

Jared Berenter, Development and Training Services (Development and Training Services)

Julie Meuller, PhD., MSI

Robert Mbeche PhD., MSI

Josiah Ateka Jomo, MSI

Margarita Vides, MSI

COVER PHOTO

An employee of the DL Koisagat Tea Company waits to weigh freshly-picked bags of tea leaf at a tea-collection station in Nandi Hills, Kenya.

Credit: Isaac Morrison, Management System International

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ACRONYMS

CEMEC	Center for Monitoring and Evaluation
CONAP	National Council for Protected Areas
CVM	Contingent Valuation Method
E3	Bureau for Economic Growth, Education, and Environment (USAID)
EWS	Early Warning System
KTDA	Kenya Tea Development Agency
MSI	Management Systems International
NASA	National Aeronautics and Space Administration
RCMRD	Regional Center for Mapping of Resources for Development
SIGMA	Geospatial Information System for Fire Management
TRFK	Tea Research Foundation of Kenya
USAID	United States Agency for International Development
WCS	Wildlife Conservation Society
WTP	Willingness to Pay

EXECUTIVE SUMMARY

Evaluation Overview

This report provides summary findings, conclusions, and recommendations for the third of three evaluation questions for a midterm performance evaluation of the SERVIR program. SERVIR, a partnership between the United States Agency for International Development (USAID) and the National Aeronautics and Space Administration (NASA), collaborates with regional partners to increase access to geospatial information and tools to improve decision-making processes. The Office of Global Climate Change in USAID's Bureau for Economic Growth, Education, and Environment 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.

This report answers the following evaluation question:

3. What is the value calculated as benefits of SERVIR's capacity building, science applications, data sharing efforts and global network?

There have been limited studies to date assessing the value of geospatial products, and even fewer examining the value of such tools and data for improving development outcomes. To understand the value and benefits of SERVIR's tools, this evaluation selected two SERVIR early warning system products for economic valuation assessments: (1) the frost mapping, monitoring, and forecasting system for farmers in frost-prone regions of highland Kenya, studied using a loss avoidance approach; and (2) a forest fire hotspot monitoring tool being used by firefighters in Guatemala, examined through a willingness to pay (WTP) study using the contingent valuation method (CVM).

Key Findings and Conclusions

The evaluation team found that both tools it assessed provide significant value to thousands of beneficiaries, demonstrating the tangible returns of SERVIR through increased access to geospatial products. The frost monitoring tool provides three days of warning, which can enable an average of $80.47 in frost-damage losses avoided for smallholder Kenyan tea farmers. These results imply savings not just to individual farmers or the Kenyan tea industry, but also suggest that the tool provides aggregate savings to the community by mitigating potential crop losses, which can improve food security and overall household welfare.

> The SERVIR frost monitoring tool could save a Kenyan tea farmer the equivalent of 25 days of household food spending or almost a full year of a child's school tuition.

> Users of the SERVIR forest fire hotspot monitoring tool in Guatemala were willing to pay an average of $78 per year for daily access to the hotspot maps, because of the tool's frequency of reporting and its reliability.

The hotspot monitoring tool in Guatemala showed positive benefits for users, who valued the tool's frequently updated, highly reliable data over its image resolution and other features. Understanding this allows the government to be more cost efficient in future investments to combat forest fires, saving scarce resources for other needs.

Frost Mapping, Monitoring, and Forecasting System in Kenya

The Kenya tea industry supports 10 percent of Kenya's population, around 3 million families. This industry is prone to damage by frost due to the altitudes in which it is grown. SERVIR, in partnership with its regional partner the Regional Center for Mapping of Resources for Development (RCMRD), developed a tool to map the frost potential with up to three days' warning. The evaluation team conducted key informant interviews, reviewed historic frost pattern data, and administered a survey of smallholder famers to assess the value of preemptive frost impact mitigation activities to reduce crop loss and damage. The evaluation team found that:

- Frost data are primarily held by the private sector and used by large tea farms, and only major incidents are typically reported. Smallholder tea farms have limited access to public data about frost patterns.
- There is a 27 percent annual chance of frost incidence for any of the farms in the study.
- Eleven percent of farmers cited frost as the most serious agricultural problem they face.
- Based on average reported losses for current and future harvestable leaf, and tea bush death, an average smallholder tea farmer in the frost-vulnerable regions of highland Kenya loses approximately $212 each year in potential income due to frost damage.
- Farmers primarily receive information via mobile phones (90 percent) and radio (88 percent), although few tea farm households have access to smart phones (20 percent) and television (27 percent).
- Nearly all farmers (99.4 percent) share or receive messages from their neighbors.
- The three-day warning that the tool provides enables an annual average reduction of $80.47 in frost-damage losses.

Based on its findings for this tool, the evaluation team concluded that:

- It is more likely that frost warnings will be received if they are sent via radio or mobile phones, rather than television or smart phones. Most farmers would benefit from an SMS system for frost warnings.
- When warnings are provided with sufficient time, farmers can address frost and minimize loss. The three-day warning allows tea farmers enough time to hire day laborers to pluck tea before damage can set in. A shorter warning time limits a farmer's ability to react and implement loss avoidance activities.

Forest Fire Hotspot Monitoring Tool in Guatemala

Sixty percent of the Petén region in Northern Guatemala – which is significant for its history, ecology, and tourism – is susceptible to forest fires. Each year national and local government actors work to mitigate these fires through the efficient allocation of firefighters and other resources. SERVIR collaborated with local institutions to develop a suite of forest fire data tools, including a monitoring product that provides near-real-time maps of thermal anomalies ("hotspots") in ground surface temperature. The evaluation team interviewed key informants, reviewed historical fire data, and – through a survey of key stakeholders – conducted a choice experiment to calculate WTP for the SERVIR hotspot monitoring tool across a suite of services. The evaluation team found that:

- Communities using the hotspot monitoring tool had fewer to no uncontrolled forest fires.
- Local farmers were more likely to follow local permitting rules for agricultural burning during fire season because they knew that all fire activity was being monitored daily.
- Of the five attributes examined for the tool, respondents were most willing to pay for "frequency of reporting" (i.e., having as close to real-time data as possible) and "reliability" (i.e., having a low

percentage of false positives). The average amounts that users were willing to pay were $66 for frequency of reporting and $12 for reliability.

Based on its findings for this tool, the evaluation team concluded that:

- The use of the hotspots maps appears to be linked to a change in behavior, potentially decreasing the amount of irresponsible agriculture burning, informing the deployment of resources to fight fires, and improving forest fire management.
- Improving the frequency with which data are provided about hotspots, and making the data more reliable, would be more useful investments than improving the spatial imaging resolution.

Recommendations

Based on its findings and conclusions for evaluation question 3, the evaluation team recommends:

- SERVIR should consider implementing a full application of the frost monitoring and forecasting system in Kenya, which should include partnering with the tea processing plants serving high-risk areas and utilizing extension agents to ensure that farmers receive SMS messages about likely frost incidents. The estimated savings from this tool could have a significant impact on smallholder tea farm households.
- SERVIR should consider applying valuation assessments such as loss avoidance and CVM to other products. These are robust and useful methods to assess the value and benefits of geospatial tools that can highlight which characteristics of a tool the intended users or beneficiaries hold to be most important, and can help shape shaping future investments or scale-ups of the tools.
- SERVIR should consider adding valuation assessments as part of its tool development process. Valuation approaches can be useful as part of early needs assessments for tool creation, or for evaluations of tool sustainability by identifying which elements of a tool are most valuable. The valuation of geospatial products can foster more efficient allocation of development assistance.

INTRODUCTION

This report provides summary findings, conclusions, and recommendations for the third of three evaluation questions for a midterm performance evaluation of the SERVIR program. SERVIR, a joint development initiative between the United States Agency for International Development (USAID) and the National Aeronautics and Space Administration (NASA), collaborates with regional partners around the globe to increase access to geospatial information and tools to improve decision-making processes. The Office of Global Climate Change in USAID's Bureau for Economic Growth, Education, and Environment (E3) commissioned the E3 Analytics and Evaluation Project[1] to conduct the evaluation, which it designed and implemented between 2014 and 2017. The evaluation is intended to help USAID and NASA better understand the use, impact, and value of SERVIR's tools, data, and capacity-building efforts for its user and beneficiary communities.

This report answers the following evaluation question:

3. What is the value calculated as benefits of SERVIR's capacity building, science applications, data sharing efforts and global network?

BACKGROUND

SERVIR

Named for the Spanish word meaning "to serve," SERVIR helps developing nations improve disaster risk management and environmental decision-making by developing the capacity of government agencies, institutions, and other key stakeholders to use and integrate geospatial and earth-observation information and technology into their decision-making processes. Under this partnership, USAID and NASA have established SERVIR regional hubs in Central America,[2] Eastern and Southern Africa, the Hindu-Kush 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 and local challenges related to disaster management, water quality, land-cover change, agriculture, biodiversity, and weather and climate.

Evaluation Approaches to Measuring Value

To answer evaluation question three, the evaluation team conducted value assessments of two different SERVIR geospatial data products, showcasing two of the primary approaches to the valuation of early warning system data. The team examined the following two SERVIR products:

- A **frost mapping, monitoring, and forecasting system** for farmers in the frost-prone regions of highland Kenya; and
- A **near-real-time forest fire hotspot** monitoring tool being used by firefighters in Guatemala.

[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.
[2] The regional hub in Central America is no longer formally affiliated with SERVIR, but several of SERVIR's geospatial data tools remain in use throughout that region.

Most economic valuation studies of geospatial data tools for early warning systems (EWS) use one of two general approaches to assessing value:

- The **measurement of loss avoidance** offers a straightforward approach to assessing EWS. It uses statistical analyses and cost estimations to determine the amount of damage that can be prevented if a warning system is in place (Klafft and Meissen, 2011), asking, "suppose you receive an alert some time before occurrence of disaster, by what percent could you reduce the disaster damage?" (Schroter et al., 2008). By calculating the damages and losses that can reliably be avoided, those damages can be interpreted as the benefits of this product. The evaluation team used this approach to assess the value of SERVIR's frost mapping, monitoring, and forecasting system in Kenya.
- The **contingent valuation method (CVM)** uses a choice experiment that assumes that when asked to choose between options, respondents will choose the option that provides them with the most utility. Respondents select from a series of choices, each with combinations of positive, negative, and neutral attributes that produce varying levels of utility.[3] Researchers obtain data on respondents' choices between options (not the actual utility obtained), and econometric estimates from choice experiments predict the probability a respondent will choose a particular option as a function of that option's attributes. Choice experiments are useful because they allow for estimating the value of products with hypothetical attribute combinations, even if some of those combinations currently do not exist. This helps to (a) identify which attributes have significant value, (b) estimate the rank or relative value of attributes, (c) predict the values of simultaneously changing multiple attributes, and (d) calculate the total economic value of the product as a function of proposed attributes. CVM is the only non-market valuation method that measures both use and non-use value, and thus provides an estimate when no clear price is available or when clear markets do not exist. The evaluation team used CVM to assess the value of the forest fire hotspot monitoring tool in Guatemala.

FROST MAPPING, MONITORING, AND FORECASTING SYSTEM IN KENYA

Background

Kenya is one of the world's four leading tea producers, and the tea industry plays a key role in the national economy. Tea contributes about 4 percent of the country's gross domestic product, offers year-round employment to about 700,000 growers in rural areas, and directly or indirectly supports over 3 million families (about 10 percent of Kenya's total population), making it one of the country's leading sources of livelihood (Mwaura, et al., 2008; Kagira et al., 2012). Tea farming in Kenya is practiced in the highlands on the eastern and western sides of the Rift Valley within altitudes of 1,500 to 2,700 meters above sea level. Because of the meteorological conditions, crops grown at this altitude are subject to many environmental threats, including drought, hail, heavy thunderstorms, and frost.

Product Overview

In partnership with the Regional Center for Mapping of Resources for Development (RCMRD), SERVIR's regional hub for Eastern and Southern Africa, SERVIR developed the frost mapping,

[3] This is known as the Random Utility Model (Bateman et al. 2003).

monitoring, and forecasting system to provide a daily map of frost potential in key areas. The application provides morning updates to end users in the Kenya Meteorological Department, private tea corporations, and individual farmers as a GeoPDF document and a link to an online web platform. This allows end users to see current and previous datasets with color-coded maps that make potential problem areas apparent. Ongoing development includes forecasting to provide a 72-hour warning of a frost event, and an automated system that creates online maps using the latest NASA data. Although this product can be accessed online by any interested party, only Kenya forecasts are available in its current host environment. Other geographic coverage is possible, but the system would need hosting and data relevant to that geographic location to be useful elsewhere.

Economic Valuation Model

The evaluation team examined the frost mapping, monitoring, and forecasting system since the tool's characteristics and context lend themselves to the application of the loss avoidance approach to economic valuation. The product itself is straightforward, the beneficiary community is known and accessible, and the tea sector has consistent and measurable elements that allow for quantification.

The evaluation team's approach to measuring the value of this product was based on a loss avoidance valuation method initially developed to measure the benefit of flood EWS in Europe.[4] This approach used four aspects of the prediction and response process to calculate value for potentially-impacted communities:

1. Personal factors (willingness and ability to respond to a warning);
2. Prediction factors (warning lead time and accuracy);
3. Dissemination factors (probability of receiving a notification in time); and
4. General factors (likelihood and severity of event, monetary benefit of preventive actions).

The objective of this study was (1) to assess the tool's utility by collecting data on Kenyan tea farmers' strategies to combatting the damaging effects of frost on their tea

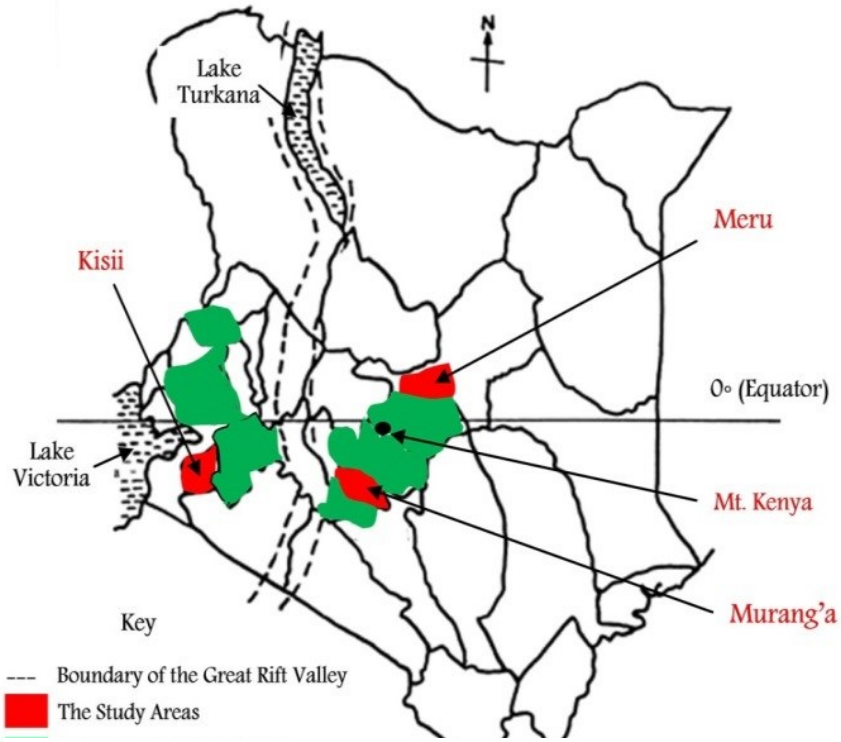

Figure 1: Study area for the economic valuation of the frost mapping, monitoring, and forecasting system in Kenya.

[4] Klafft and Meissen (2011) proposed an advanced model that is disaster-independent and has the strength to take human behavior into consideration. Applications of the advanced model include Wurster and Meissen (2014), who used it to assess the economic benefits of flood EWS for private households in Germany; and Wurster et al. (2015) who assessed the economic benefits of EWS applications for companies in the context of hydrological hazards. Some adaptation of the model was required to reflect the distinct challenges of Kenya, but the original model proved quite flexible in its structure, making this relatively straightforward.

crops and harvests, and (2) to use that information to assess the likely future value of this product's predictive capabilities for the Kenyan tea sector. This value includes the potential mitigation of frost-induced crop loss and damage, as well as the avoidance of unnecessary preventative action and associated product devaluation. Findings from this study can inform the further development and application of a broader frost EWS and response program for the Kenyan tea industry. In addition, the findings provide insights into the advantages and limitations of the SERVIR product data, along with suggested avenues for its successful dissemination.

The research focused on:

- Characterization of Kenyan tea producers;
- Effects of frost on tea production in terms of frequency and severity of events;
- Responses to a frost event by Kenyan tea producers; and
- The economic value of EWS to the Kenyan tea sector.

The equation below[5] summarizes the benefits of all types of protective actions taken by tea households in the study area to minimize frost losses (due to a frost event) as a result of warnings from the SERVIR product. In the model, benefits will only materialize for those households that are likely to face frost events over the period of economic assessment (time t). After calculating the overall positive impact of the EWS, the impact was adjusted to account for the cost of preventive actions. In addition, the benefits make use of dynamic investment calculation principles.

$$\left[Bft_{EWS} = \sum_{i} t\ [P(Di).\ P_{pred}\,(Di).H.LHooD_{action\,,i,C}.Bft_{prot.,i\,,C}.\ Inc_{prot\,i,c} \right]$$

Where:

- Bft_{EWS} The benefits associated with frost EWS.
- t The time span of economic assessment
- $P(Di)$ The number of projected frost events per unit time within the study area/ probability that frost happens per unit time in the warning area.
- $P_{pred}(Di)$ The probability that a frost event is correctly predicted.
- H The number of households in the warning area
- $LHooD_{action\,,i,C}$ The likelihood that the household will perform relevant protective action in case of frost due to an early warning alert.
- $Bft_{prot.,i\,,C}$ The preventable damage if preventive actions are implemented following receipt of an alert. This will be derived from the monetary value of frost damage in case of a frost attack and the percentage by which the household can reduce the damage if an early alert is received. In addition, calculating the benefits of EWS will consider whether farmers might have taken the same protective action even without a EWS (e.g., because of existence of EWS based on indigenous knowledge).
- $= Inc_{prot.,i\,,C}$ The costs of implementing preventive action

[5] Based on Klafft and Meissen (2011) and Wurster and Meissen (2014).

This model is based on three groups of factors:[6]

1) **Disaster-specific factors** include the probability of the occurrence of a specific disaster per time unit in the warning area.
2) **Personal factors** include factors that influence how a warning is processed by recipients, and if and how it is then translated into preemptive action. This model focuses on measuring:
    a) The likelihood that the household will receive a correct warning. The study models (i) the likelihood that an appropriate number of responsible persons per household will subscribe to the frost EWS and adjust to account for secondary-level notifications through neighbors, and (ii) the possibility that the communication channel would be nonoperational at the time of issuing notification.
    b) The likelihood that the household will take relevant preemptive action in case of a frost event. This considers the willingness and ability to undertake preemptive actions against frost damage. Ability is measured in terms of capacity to mobilize resources to undertake action.
3) **Prediction-related factors** include the probability that a disaster is correctly predicted and based on the accuracy level of the SERVIR product.

Study Methods

The evaluation team used qualitative and quantitative methods to collect reliable data on issues related to frost and the Kenyan tea sector. There was limited information available on the frequency and severity of frost occurrence in the highland regions, the impact of frost on tea production yields, existing methods for frost prediction, frost damage mitigation strategies, and communication network access among tea farming communities in this region. The evaluation team conducted key informant interviews, quantitative surveys, and reviews of secondary data on historic frost data patterns to estimate the value of the frost mapping, monitoring, and forecasting system.

The first phase of data collection involved over 30 key informant interviews with stakeholders in the Kenyan tea sector, including the Tea Research Foundation of Kenya (TRFK), the Kenya Tea Development Agency (KTDA), agricultural insurance agencies, and tea producers from smallholder and estate farms in Kericho and the Nandi hills. The team also analyzed relevant tea sector documents and collected historical data on frost patterns in the vulnerable regions from large tea companies in Kericho and the Nandi hills. These data enabled the team to calculate the upper range of the product's future value at various levels of adoption and use.

In the second phase of data collection, the evaluation team worked with a local survey research firm to administer a questionnaire to 427 smallholder farmers in the two frost-prone areas of Kenya: West of Mau (Kericho and Bomet counties) and East of Mau forest (Nandi County). The survey collected data on farmers' demographic and socioeconomic characteristics, tea inputs and outputs, frost-related characteristics, and the groups of factors noted above.

[6] Wurster and Meissen (2014) included a fourth category that covered dissemination-related factors such as the number of subscribers for EWS and multiplier effects (e.g., recipients pass the warning to neighbors). In the present study, this was covered under the personal variables.

Study Findings

How tea is grown and harvested is central to the issue of frost and frost damage. Tea is a perennial crop that continually puts out new leaves, which are then harvested and processed into commercial tea year-round. After the youngest leaves are plucked from the tops of the tea bushes, each bush takes approximately two to three weeks to produce a new batch of leaves for plucking. This creates a continual harvesting rotation, with pluckers moving from one section of the tea field to the next as the leaves come into readiness. Frost not only damages the young leaves, but also interrupts the growth cycle. A tea bush struck by frost may stop producing new leaves for one to three months, depending on the severity of the frost event, and may even die from a particularly bad frost.

Figure 2: Healthy tea leaves (left), and a tea leaf showing frost damage (right). *Credit: Isaac Morrison, MSI.*

Impact of Frost

The evaluation team found few existing records on frost events in the tea sector. Although some of the larger estate farms and the TRFK kept limited reporting data on losses from frost damage, no other consistent data were available. The evaluation team thus included specific questions on recent frosts experienced by local farms.

The study calculated a 27 percent annual chance of frost incidence for any of the farms in the study. **Eleven percent of farmers cited frost as the most serious agricultural problem they face.** Based on average reported losses for current and future harvestable leaf, and tea bush death, an average smallholder tea farmer in the frost-vulnerable regions of highland Kenya loses approximately $212 each year in potential income.

To minimize recall bias, the team asked farmers for specific information about frost events from the past 2 years, as well as information on the most severe frost in the past 20 years.[7] The team cross-checked this information with the limited available records kept by larger estate farms to calculate the likely frequency and severity of average yearly losses from frost damage. The evaluation team found that frost is a serious and frequent problem in the study area. It calculated a 27 percent annual chance of frost incidence for any of the farms in the study. Eleven percent of farmers interviewed cited frost as the most serious agricultural problem they face. Damage from frost was substantial, with up to several thousand bushes affected in any given event. Farmers indicated that damages range from loss of harvestable young leaves to plant productivity stalling out for 30 to 90 days, and severe frosts may cause the plant to die. Based on average reported losses for current and future harvestable leaf, and tea bush

[7] If other than 2014-2015.

death, an average smallholder tea farmer in the frost-vulnerable regions of highland Kenya loses approximately $212[8] each year in potential income from frost damage.

Existing Frost Prediction and Early Warning Methods

Although some farmers stated they could sometimes predict an evening frost on the morning of the same day, no useful preventative action can be undertaken within that timeframe. The 72-hour warning that the SERVIR tool provides is unprecedented for Kenya's tea-growing sector. **At this time, no medium- or long-range prediction methods are available to tea farmers**.

Access to Early Warning Messaging

The value of the warning is based, in part, on the likelihood of those who would be most affected by the frost receiving the warning. The evaluation team assessed this likelihood by asking if respondents had access to key communication channels, including the probability that those who receive the warning would share it with their neighbors.

Based on survey responses, most tea farmers across the three counties have access to radio (88.8 percent) and mobile phones (90.2 percent), but far fewer have access to television (27.2 percent) or smart phones (20.6 percent). The implication is that, if early warnings were to be sent through radio and/or mobile phones, at least 8 in 10 farmers in the study area would be reached. It also appears highly likely that those receiving messages would share them with neighbors, as 99.4 percent of respondents said they were likely or very likely to share the information.

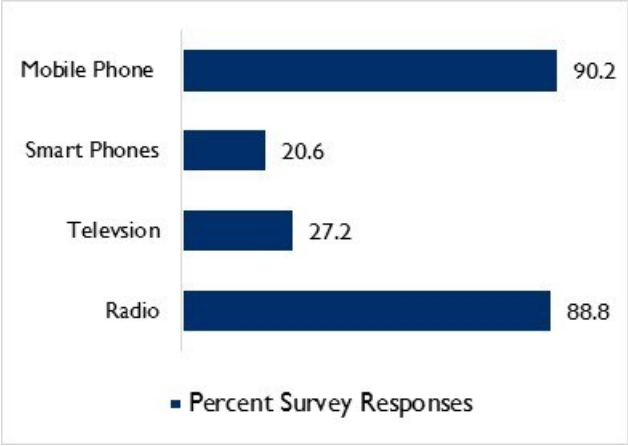

Figure 3: Access to potential early warning channels among Kenyan tea farmers in the study area.

Because of the nature of the tea industry, there is a strong, mutually-beneficial relationship between small-scale tea growers and the facilities that process the raw, freshly-plucked leaf. Even tea processing facilities with their own tea growing estates are heavily reliant on tea from smallholder farmers; they are responsible for growing 40 to 60 percent of the facilities' product. To facilitate this process, thousands of tea collection centers operate throughout the tea growing regions of Kenya. These collection centers, often little more than a corrugated roof with a crossbeam for hanging scales to weigh the sacks of fresh tea, are located such that even the smallest tea farm is rarely more than a couple of kilometers away from a collection center. Each collection center has a distinct identification number known to the farmers who use that center, and the locations are also geo-located so the coordinates can be placed on geographic information system maps.

The tea processing facilities maintain registries of all farmers who sell them raw leaf. That information includes each farmer's identification number, name, collection center number, and telephone number (if known). According to managers at several of the processing facilities, more than 90 percent of farmers who are registered with them have phone numbers. While no current SMS subscription exists, at least three of the processing facilities intend to use their farmer registries to send general SMS messaging alerts to their registered farmers in the future.

[8] All dollar amounts provided in this report are in U.S. dollars.

Damage and Loss Mitigation Strategies

A variety of approaches to frost prevention have been attempted in other locations and with other crops, but most are not available to smallholder tea farmers due to cost or logistical inconvenience.[9] **Only two strategies are regarded as viable for the short-term mitigation of frost-induced tea damages:**

- **Early harvesting:** Young tea leaves are viable for plucking for about 8 to 10 days, and because of the continuous harvesting rotation, there are always new leaves available for plucking. Manpower availability estimates based on survey data and conversations with tea growers indicate, in most cases, 72 hours is sufficient notice to mobilize additional pluckers and salvage all available leaves before frost strikes. Although the quantity of leaves salvaged in this fashion would only provide a small hedge against the next month(s) with little or no harvest, the mobilization of that manpower also lends itself to skiving (described below).
- **Skiving:** Frost damage most heavily affects the youngest leaves, while older leaves and branches can more readily resist its effects. Skiving, also known as skiffing, is a procedure that involves light pruning to remove the topmost layer of foliage from the tea bush. Removing these vulnerable parts of the bushes reduces shock from damaged young leaves and makes the plants better able to resist the frost's effects. Doing so speeds up the post-frost recovery time, and bushes begin giving off new leaves sooner than they would have otherwise.

Figure 4: Tea farmers demonstrate skiving technique to an evaluation team member. *Credit: Isaac Morrison, MSI.*

Survey data and conversations with tea farmers confirmed the viability of these methods and the importance of the 72-hour warning provided by the SERVIR tool. Tea that is freshly plucked must be taken to the processing factory the same day, and many farmers rely on assistance from hired day laborers when additional plucking is needed. A tea farmer who receives a three-day warning before an impending frost has enough time to contact extra tea pluckers and to complete a full plucking of all available tea in time; a shorter warning window makes that rapid turnaround less likely or even impossible.

Savings from Preemptive Action

The average smallholder tea farming household in the frost-vulnerable regions in this study has, on average, a 1.04-acre plot of tea bushes, which generates a net income of $1,075 each year.[10,11] Based on

[9] The two most common long-term strategies for mitigating frost damage are the planting of trees throughout the tea fields and the replacement of conventional tea bushes with frost-resistant hybrid tea strains. Trees, if planted strategically, can disrupt the flow of cold air that causes frost, reducing its extent and severity. Frost-resistant varieties have shown a high level of success, but generally produce lower yields than conventional tea bushes.

[10] The region-specific household information collected for this study is consistent with other national data on Kenyan smallholder tea farming from the Kenyan Ministry of Agriculture and the TRFK.

[11] Average annual gross income from tea is approximately $1,700 before plucking, tipping, fertilizer, and pruning costs.

these data, a smallholder tea farming household that receives a three-day warning before a frost and implements preemptive plucking and skiving[12] would see an annual reduction in frost-damage losses of approximately $80.47.

This represents a substantial potential benefit to tea farmer households:

- **Food:** The prevented loss of $80.47 would allow the average survey household[13] to buy food for about 25 days.
- **Education:** The Kenyan government's gazetted fees for secondary schools is $93.74 per year, so the $80.47 estimated preventable loss could cover over 88 percent of tuition fees for one child in a secondary day school in Kenya.
- **Medical expenses:** The estimated preventable loss could cover a substantial share of a Kenyan household's medical expenses. Average per capita combined spending for all inpatient and outpatient health services in 2013 in Kenya was approximately $16.09. The $80.47 estimated preventable loss thus represents approximately a full year of a household's total health spending.

Larger tea-growing companies in the region will also benefit from the EWS, but since the size and capacity of these institutions varied substantially, the evaluation did not attempt to quantify the dollar value benefit of the EWS to these companies. Nonetheless, the evaluation team spoke with representatives from six large tea growing estates and found high interest and enthusiasm for the money-saving potential represented by the three-day pre-frost warning.

Study Conclusions and Recommendations

The evaluation team concludes with a high level of confidence that the 72-hour warning provided by SERVIR's frost mapping, monitoring, and forecasting system can provide real benefits to hundreds of thousands of smallholder tea farmers in the frost vulnerable regions of highland Kenya – if it can be combined with an effective messaging system and successful implementation of both early plucking and skiving by the tea farmers. The processing facilities' existing tea farmer registries and proposed bulk SMS communication messaging systems provide a near-turnkey solution to the large-scale communication of frost warnings. Furthermore, even when instances of frost are likely to be highly localized, geo-located tea collection centers can easily serve as reference points for indicating the approximate location of those frost events (e.g., "high likelihood of frost near tea collection center #12345 and 12346"). In addition, the early plucking and skiving methods are identical to those already used by tea farmers, and thus require little or no specialized training.

[12] This total savings includes the cost of hired pluckers/skivers.
[13] Average household size in the regions under review is approximately five people.

The evaluation team recommends that full application of SERVIR's frost mapping, monitoring, and forecasting system include outreach to all tea processing plants serving the frost vulnerable highland regions to develop a comprehensive EWS that can send SMS messages to all registered farmers prior to a moderate- or large-scale frost event. This, in conjunction with the use of tea collection center identification numbers, would minimize any requirement for individualized messaging, as warnings could be tied to the location of the tea collection centers, rather than the location of the individual farms.

Additionally, to facilitate participation in the system, SERVIR and its local hub should work with the tea processing plants and local agricultural extension officers to ensure that farmers in the region understand the frost warning messages and how they should respond to the frost.

FOREST FIRE MONITORING IN GUATEMALA

Background

Guatemala's northernmost department of Petén encompasses approximately a third of the country's national territory. Petén includes 13 municipalities, more than 800 communities, and over 25,000 square kilometers of protected areas[14] that have extensive historical, scenic, recreational, archaeological, and biodiversity value. Petén is also highly susceptible to forest fire, and approximately 60 percent of its protected areas are regularly affected by forest fires. Popular tourist areas and highly sensitive historical sites receive local investment to build fire breaks, but in most areas breakage in vegetation is non-existent. Without divisions or fragmentation in the vegetation, conditions in Petén are ripe for forest fire for a third of the year. This places a heavy burden on the local, regional, and national institutions responsible for battling the persistent threat of fire with limited resources.

Product Overview

The Geospatial Information System for Fire Management (SIGMA-I) is a suite of Earth observation products designed to inform prevention and control of forest fires in Petén. SERVIR provided technical and financial support for the development of SIGMA-1 through Guatemala's Center for Monitoring and Evaluation (CEMEC) at the National Council for Protected Areas (CONAP) in Petén.

The most widely used component of SIGMA-I is a fire monitoring approach that produces near real-time data to map "hotspots," or thermal anomalies in ground surface temperature. During the annual fire season (typically March through June), CEMEC disseminates hotspot maps daily through an email listserv to alert key stakeholders in Guatemala's forest fire management network, known as the Forest Fire Prevention and Control System, of likely forest fire activity. Use of the SIGMA-I tools is also highly

[14] Secretaría de Planificación y Programación de la Presidencia (Segeplan). (2013). Diagnóstico Territorial de Petén.

responsive to regional agricultural activity, as farmers use small controlled burns to clear cropland before planting in advance of seasonal rains – an activity that significantly raises fire risks in that region.

During fire season, hotspot information is disseminated daily by email to first responders and government forest fire officials throughout Petén, as well as to non-governmental actors such as Wildlife Conservation Society (WCS), ProPetén, Defenders of Nature Foundation, and University of San Carlos. In protected areas, response to hotspots (by CONAP or partnering non-governmental organizations) is automatic. In farming communities, local councils enforce time- and location-specific burn calendars for farmers; where hotspot locations do not coincide with planned burnings, response teams are dispatched to locate and, if necessary, control the fire.

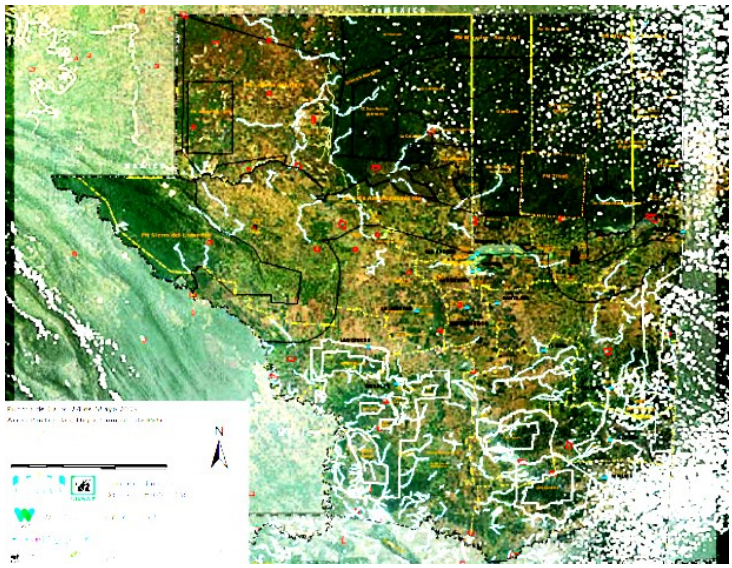

Figure 5: Hotspot map distributed by CEMEC. May 24, 2016. *Credit: CONAP*

Economic Valuation Model

To quantify the value of the hotspot mapping component of the SIGMA-I tools, the evaluation team designed and implemented a choice experiment to assess the product's perceived value by users, as demonstrated through their expressed willingness to pay (WTP) for the product and service. Choice experiments are based on the assumption that, when asked to choose between options, respondents will choose the option that provides them with the most utility (satisfaction). Respondents obtain utility from the attributes of the option, and varying levels of the attributes will result in varying levels of utility.[15] Once these data are obtained, the model predicts the probability that a respondent will choose a particular option as a function of that option's attributes. Data for this type of study are collected through a carefully designed survey instrument administered online.

For this study, the evaluation team conducted field work in Guatemala to observe the country's forest fire management systems and better understand the context and conditions under which SGMA-I's hotspot mapping component is used. The team conducted interviews with stakeholders involved in the development, dissemination, and use of the hotspot maps at all levels of government. Stakeholders included decision-makers in Guatemala City and two locations in Petén: Flores (where departmental forest fire management organizations are based) and Uaxactún (the location of forest fire-vulnerable communities). Table 1 summarizes the locations of these organizations.

[15] This is the Random Utility Model. Economists call the utility "random" because each respondent's choice has an unobserved component influencing his or her choice. Since researchers only observe the respondent's choice between options (not the actual utility obtained) econometric estimates from CE assume a probabilistic approach.

TABLE 1: ORGANIZATIONS IN GUATEMALA'S FOREST FIRE MANAGEMENT SYSTEM

Organization	Location
ProPetén	Flores
CEMEC	Flores
OMYK	Uaxactún
Yaxha	Yaxha-Nakum National Park
CONAP – Laguna del Tigre	Flores
WCS	Flores
Defenders of Nature Foundation (Sierra del Lacandón National Park)	Flores
Center for Conservation Studies, University of San Carlos	Guatemala City
System for the Prevention and Control of Forest Fires	Guatemala City
Corozal Forest Fire Council	Corozal

The unique focus of the choice experiment to estimate a product's benefits in a developing country via an email survey limits its generalizability to other contexts. However, if attributes have a statistically significant value for the hotspot monitoring product in Guatemala, value estimates of attributes can inform investments in future product development and provision to maximize the value of similar products in other contexts.

The evaluation team, with the support of CEMEC, sent the online survey link to 159 individuals on the email listserv that CEMEC uses to distribute the daily hotspot maps. This list gave the team a remarkable level of access to the stakeholder community working in Petén's forest management and firefighting field. Stakeholders were asked to express their preference among various design options of the hotspot mapping product. Each option, or "choice set," represents a combination of select product attributes. In consultation with practitioners familiar with the product, the team selected, defined, and assigned levels to the attributes comprising the choice sets. Table 2 shows the characteristics of the choice sets.

TABLE 2: CHOICE SET ATTRIBUTES, UNITS, AND LEVELS

Attribute	Units	Levels
Spatial resolution	Meters	100, 500, 1000*
Frequency of reporting	Time	Twice-daily, daily*, weekly
Climate forecast	Days advanced notice	Current day, 8-day*, 15-day
Land use/land cover mapping	Time	Weekly, bi-weekly*, seasonal
Accuracy	Percentage of false positives	5%, 15%*, 25%
Cost	Quetzales	200, 500, 1200, 2000, 2600, 3300, 4000

*indicates "status quo" option C, cost of option C = 0

By selecting from sets of combinations of attributes, respondents make implicit tradeoffs and, in so doing, identify the product attributes that provide them with maximum utility. For this choice experiment, the third choice, "C," represented the status quo of current attributes of the SIGMA-1 hotspot monitoring tool. Each choice set is designed with various levels of specific attributes. These are randomly assigned using an algorithm that ensures efficient combinations of attributes per choice set. Each respondent answered a series of 10 choice sets. A sample choice scenario is represented in Table 3, with a hypothetical selection circled in blue:

TABLE 3: SAMPLE CHOICE SCENARIO

	A	B	C (status quo)
Spatial Resolution	100m	500m	1000m
Frequency of reporting	Twice daily	Weekly	Daily
Climate Forecast	Current day	15 days advance notice	8 days advance notice
Land use/land cover mapping	Weekly	Seasonal	Bi-weekly
Accuracy	5% false positive	25% false positives	15% False Positives
Annual cost	3300 Q	1200 Q	0Q

Eighty-five of the 159 individuals (53 percent) responded, resulting in 2,550 complete observations. Because the utility function is probabilistic, limited dependent variable estimation techniques were needed to estimate the econometric model. The team used a conditional logit model to predict the probability that a respondent would choose a particular option. The team estimated the conditional logit using maximum likelihood. All attributes were included as explanatory variables, and an alternative specific constant (status quo) variable was added.

Choice experiment results are directly related to the set of attributes and choices presented to respondents in the study's design. If one of the attributes includes a price or cost in monetary terms, the estimation results will provide a monetary value associated with the level of each attribute, as well as tradeoffs between the attributes. While choice experiments have several benefits relative to other methods of non-market valuation, the generalizability of the results is constrained both by the nature of the sample and the definition of the attributes.

The approach provides a unique opportunity to estimate values of attributes that are difficult to estimate using other methods of valuation. Construct validity, or how accurate the measures of valuation are, can be verified by comparing the results to similar valuation studies using stated and revealed preference. Content validity, or the degree to which other contextual factors are considered, is ensured through careful development of the survey instrument.

Study Findings

Effects of the Forest Fire Monitoring Tool

Based on its key informant interviews and analysis of secondary data, the evaluation found that the use of SIGMA-I's hotspot maps as an EWS is causing more responsible agricultural burning, informing deployment of resources for forest fire prevention, and contributing to significant improvements in forest fire management in Petén. Forest fire response data provided by Guatemala's National Forestry Institute indicate declines since 2006 in cumulative surface area damaged by fire, surface area damaged in proximity to cultivated areas and forests, response time to forest fires, and resources used to control forest

"The department's work is protection, which happens in consort with conservation organizations. At the beginning of 2002 or 2003, we would be informed of a fire and it could take up to a day to find the fire because we had to search for the smoke rising from the canopy of the trees. Now we receive a map in PDF, which allows us to search using coordinates. Before it was possible that we would not find out about a fire until it had already gone out. Fires have decreased significantly. Tablets are being used in the field, and hopefully we will soon be able to manage information in real time from the field."

- WCS officials in Flores, Petén describing the importance of satellite-based hotspot mapping (February 2015)

fires. **WCS officials noted that, in the three communities where it operates, no uncontrolled forest fires have occurred since adoption of the SIGMA-I tools**.

A reduction in documented "intentional" fires during this time further supports accounts from WCS and others that the use of the hotspot maps for fire detection has built community awareness and changed community behavior in Petén communities. People are now less likely to engage in illegal agricultural burning, for example, knowing that illicit fires are likely to be detected by CONAP and its partners.

Critical to these successes is the fact that SIGMA-I and its hotspot maps are part of a larger pool of information that contributes to planning and decision-making regarding public-sector investment and institutional presence in Petén. On-the-ground reporting and ground patrols monitor fire activity as well as threats unrelated to fire, such as deforestation and the trafficking of wildlife and cultural artifacts. CEMEC and other actors conduct periodic aerial monitoring, particularly over isolated areas and during critical periods. The impact of SIGMA-I is contingent upon adequate and continued investment of resources for these components to operate effectively.

Value of the Forest Fire Monitoring Tool

The choice experiment results indicate that members of the user community hold the **frequency of reporting and low percentages of false positives as the most important attributes** of the SERVIR hotspot monitoring tool. Value estimations for land use/land cover mapping (which regularly updates to show changes in land cover from deforestation and other causes), climate forecast, and spatial resolution fell outside of a 95 percent confidence interval, and therefore the model did not regard these as statistically significant.

TABLE 4: WTP RESULTS (QUETZALES) FOR ALL ATTRIBUTES

	WTP	Lower 95% CI	Upper 95% CI
Spatial Resolution	0.66	-0.04	1.35
Frequency of reporting	499.55	84.75	914.35
Climate Forecast	35.12	-23.19	93.42
Land use/land cover mapping	343.67	-66.60	753.93
Accuracy	90.99	46.76	135.22
Total	**969.99**		

Although the estimated model shows an annual WTP of 969.99 quetzales (Q), equivalent to $128.34,[16] for the hotspot monitoring system, the evaluation team has less confidence in these estimates because of the statistical insignificance of resolution, forecast, and land use. The challenge here is that WTP may not be different from zero for the three attributes that are not statistically significant. However, the parameters for the land use/land cover mapping attribute indicate a very high WTP (343.67Q), but also a very large variance in range. This suggests that frequent updates indicating land use/land cover change on the hotspot map would have a high value for some individuals, but little value to others. This is likely attributable to variation across respondents' job responsibilities, but further conversation with informants would be necessary to confirm this.

Ultimately, the **implied ranking of the attributes** based on WTP (with 1 being most important) was:

1. Frequency of reporting
2. Reduction in false positives

[16] All quetzal-to-dollar conversions are based on the rate of exchange taken on February 28, 2017, the closing date for the online survey: 1 Quetzal = $0.1323 USD.

3. Land use/land cover mapping
4. Climate forecast
5. Spatial resolution

Frequency of reporting had the highest marginal WTP. The evaluation team also found a positive and statistically significant WTP in the low incidence of false positives. Table 5 shows the WTP results for those two statistically significant attributes, within the lower and upper bounds of a 95 percent confidence interval. The average WTP for the current frequency of reporting is 499.99Q ($66.10), and the average WTP for the current false positive percentage rate is 90.99Q ($12.04), indicating that the hotspot monitoring system has a total annual WTP of 590.54Q ($78.13) for individuals who currently receive it.[17]

TABLE 5: WTP RESULTS FOR STATISTICALLY SIGNIFICANT ATTRIBUTES

	WTP (Quetazles)	Lower 95% CI	Upper 95% CI
Frequency of Reporting	499.55	84.75	914.35
Percent False Positives	90.99	46.76	135.22
Total Annual Value	590.54		

Study Conclusions and Recommendations

The evaluation's findings provide statistically significant results that the SERVIR hotspot monitoring tool has positive non-market benefits for its users. Further, the findings show that the frequency of reporting has the highest relative value for the study respondents, followed by reductions in false positives. If SERVIR's goal is to improve the marginal benefits of hotspot monitoring, it should prioritize improving the frequency of reporting and reductions in false positives.

While the study sample was restricted to users of the hotspot monitoring product, the beneficiaries of the product include users and community members who benefit from improved wildfire management. In addition, survey respondents were likely answering the questions based on their workplace budget constraints. While the study is valuable in communicating relative values of product attributes, the results would be even more meaningful if they were supplemented with a survey of community members about their valuation of improved wildfire management. Furthermore, several respondents mentioned that the tool itself was "priceless." If respondents feel the tool is essential, the cost attribute may not have been acting as a useful constraint. Regardless of these potential challenges, the results do indicate the relative values of tool attributes, and a positive and statistically significant value of the tool overall.

FUTURE APPLICATIONS OF VALUATION METHODS

Valuation of geospatial data for EWS applications and related disaster response activities is a developing field. The methods and data presented in this report represent not only a useful insight into two of SERVIR's noteworthy geospatial data products, but also a contribution to the broader geospatial data valuation field, as limited studies of this nature have been conducted. This is underscored by a growing demand for quantifiable results that can support or clarify qualitative discussions of value. Toward that end, this section provides general comments on the two approaches used in this report.

[17] In this context, it may be useful to think of annual WTP as similar to a software subscription or utility bill.

Contingent Valuation Method

The use of CVM to calculate value is increasingly prevalent in the environmental literature. Assessing the value of health, biodiversity, and other similar, often non-tangible factors, is essential in decision-making, yet hard to do when there are no clear prices. CVM is often the choice method for assessing the value of public goods that are non-excludable and non-rivalrous (i.e., their use by one individual does not preclude someone else from using them as well). CVM is only recently being applied to the assessment of data and geospatial tools such as those created by SERVIR, which to some extent can be presented as public goods. The strength of CVM lies in its ability to capture both use and non-use value, to be either a standalone piece or part of a cost-benefit/cost-effectiveness analysis. Although prices exist for the cost of geospatial data, these are often subsidized. The true value of geospatial tools and data often lies in the access and not the product itself; the value of this access is rarely measured. **Future SERVIR products, particularly data products, would benefit from having CVM studies for impact evaluations, to expand the value of benefits to include non-tangibles, and as an approach to determine the ranking of attributes related to their worth.**

Strengths of the Approach

The SERVIR hotspot monitoring data provide public benefits that are not easily determined by market values. Non-market valuation provides tools to estimate the values of goods and services that are not bought and sold in traditional markets. The tools of non-market valuation are therefore essential when evaluating the effectiveness of programs of this nature.

Limitations of the Approach

Gathering CVM data carries an expectation of informant literacy, as it usually is done through a survey. Although enumerators can be used to gather data, the WTP question is usually presented as a dichotomous choice. In some studies, CVM surveys find open-ended questions more appropriate for calculating value. However, in a development context – particularly with very poor communities where income is often unstable – WTP questions are not bound and thus often present inaccurate values.[18] Another limitation in the method lies in the application of CVM, as choice questions are often not crafted carefully. One of the primary sources of error and criticism of CVM lies in poorly designed questions.[19]

Loss Avoidance Measurement

The direct measurement of damage and losses avoided through EWS is a particularly appealing approach to the valuation of geospatial data. Unlike CVM, the method is clearer and more straightforward for less specialized audiences. As seen in the Kenya case, the data collection process itself can provide useful insights into the context in which the geospatial data tools are applied, facilitating adjustments to the tool and data delivery, as well as to the useful application of the data.

Strengths of the Approach

One of the most useful aspects of this product is that the model reflects human behavior in response to data and can be adjusted to see how changes in behavior will increase or decrease the potential value of

[18] http://www.fao.org/docrep/003/x8955e/x8955e03.htm#P103_41342.

[19] Whittington (2002) claims that many of the CVM studies in developing countries are inaccurate and unreliable, due to (i) poorly administered and executed studies, (ii) poorly crafted scenarios, and (iii) failure to conduct split-sample experiments to assess the robustness of the results.

the geospatial data being presented. Additionally, because it calculates benefits in concrete dollar values, it lends itself to integration into cost-benefit analyses.

Limitations of the Approach

The major limitation of this approach concerns the information required. Often the data needed do not exist or cannot be accessed, making analysis difficult. When data are found or available, these tend to be incomplete, small in size, and for limited time periods. Damage and loss assessments work better when clear prices are known. Costs related to disasters may not always be transparent or shared openly. Additionally, the detailed and specific insights that this approach produces are limited in their generalizability. Variation between populations and circumstances can produce a wide range of effects, and multiple studies will likely be needed for multiple use cases.

ANNEX A: FROST SURVEY INSTRUMENT

Socioeconomic Survey Questionnaire for Tea Farmers in Kericho, Bomet, and Nandi Counties

Introduction

Good morning/ afternoon/evening. My name is …… from Research Solutions Africa (RSA), a Market and Social Research firm based in Kenya. On behalf of Management Systems International (MSI) and the United States Agency for International Development (USAID), we are undertaking a study that seeks to develop understanding of the effects of frost on the tea harvests in Kenya, and how the tea farmers respond to those effects. As part of the research, we are currently conducting a survey of smallholder tea farmers in Kericho, Bomet and Nandi Counties, and the findings of the survey will be used to inform frost early warning and protection programs in the tea industry in Kenya.

You have been randomly identified as one of the respondents in the survey, and your participation is entirely voluntary. The interview is likely to take about 20-30 minutes, and there is no right or wrong answers. All of the information that you share with us today will be kept strictly confidential, and your name or identity will not be connected to any of your responses at any point.

If you have any questions about this survey, you may contact **Collins Athe** (***the Survey Field Supervisor***) from RSA or **Robert Mbeche** from MSI.

Are you willing to take part in this interview?

1. Yes >>> ***Proceed***
2. No >>>***Thank the respondent, terminate interview and move to the next target household***.

Tracking: General Identification: To be filled by the enumerator

HH identification number				
Name of factory registered in				
Name of buying centre				
Code of buying centre				
Registration No.				
Name of respondent				
Telephone contact				
Date of interview:	DD MM YY			
Time of interview (24-hour clock):	**Start** HH MM		**Stop** HH MM	
Name of interviewer:				
Place of interview:	County			
	Sub County			
	Ward			
	Location			
	Village			
	GPS/GPRS coordinates			
Number of visits (max. of 3)				
Reason for call back		**Number of visits**		
		1	2	3
Refused to be interviewed			1	1

Target respondent not at home	[redacted]	2	2
Target respondent requested for a call back			
No one in the household		3	3
Respondent not able to be interviewed due to medical reasons (very sick, dump, etc.)		4	4
No adult member in the household		5	5
Language barrier		6	6
Not applicable		99	99
Outcome of final visit	**Successful**	**Incomplete >> END**	**Replaced >> END**

Field quality control checks			
Activity	Activity undertaken by		
	Interviewer	Team leader	Supervisor
Reviewed			
Accompanied	[redacted]		
Back checked			
Called back			

Section A: Demographic and Socioeconomic Characteristics

1) Household Roster

Please tell me who are the members of your household?

Note: A household is defined as persons regularly sharing meals and living in the same housing unit for the past 6 months. Start with the respondent him/herself.

Person ID	First two names	Sex 0=Male 1=Female	Relationship to household head **[Refer to Code 1]**	Age [*write 0 if less than 1*]	Years of education [*for person >15 years only*]
1	**= Household head**				
2	**= Spouse)**				
3					
4					
5					

Code -1. *Relationship with household head:*

1= Households Head, 2 = Wife/Husband, 3 = Son/Daughter, 4 = Brother/sister, 5 = Father/mother, 6= father-in-law/mother-in-law,

7 = Son-in-law/daughter-in-law, 8 = Brother-in-law/sister-in-law, 9 = Grandson/granddaughter, 10 = Nephew/Niece, 11 = Other Relatives, 12=servant, 98=other (specify)

2) Household Demographic and Social Economic Characteristics

Question	Indicator	Response
1. What is the size of your farm in acres?	*Actual acres/hectares (including land under crops, livestock and homestead)*	
2. What is the nature of tenure?	*1= title 2= leasehold 3= communal 98= other (specify)*	
3. Where does household head reside?	*1=within homestead; 2= town or other village;*	
4. Where does spouse reside?	*1=within homestead; 2= town or other village; 99=not applicable*	
5. What are the most important crops produced by your household for income? (List maximum 3 crops)?	i.	
	ii.	
	iii.	
6. Who makes most of the farming decisions on each of the above listed key crops?	*1= husband 2= wife 3=both husband and wife 98=other (specify)*	
7. Are your crops insured by any agricultural insurance agencies?	1=Yes; 0=No **>>9**	
8. If yes, where?	Open-ended	
9. If no, why not?	1=Too expensive 2=Don't know how to get insurance 3=Don't understand insurance 4=Don't trust insurance 98=Other (specify)	
10. If no in Q7, are you planning on getting agricultural insurance in the next year?	1=Yes 2=No	
11. Are you or any member in your household a member of a recognized farmers' group or association?	1= yes 0= No **>>13**	
12. If yes, what is the name?	*Open-ended*	
13. If yes in Q11, what type of group is it?	1= Dairy or agricultural society 2= SACCO 3= informal self-help group 98 = other (specify)	
14. Did the household obtain any credit / loan in the last 12 months?	1=YES; 0= No **>>16**	
15. If Yes in Q14, what for?	*Open ended*	
16. If yes (in Q13), who provided the loan?(*Multiple response)*	1 = Friend/family 2 = Bank 3 = Table banking /Microcredit 4 = Co-op/SACCO 98 = other (specify)	
17. Was any part of the loan used to finance tea farming operations?	1=YES 0= No	
18. If no in Q14 above, why not?	1= Did not seek/apply for loan 2=Application was declined 98=Other (specify)	
19. Name of nearest town	*Open-ended*	
20. What is the distance from the homestead to nearest market?	Actual distance in kilometres	
21. What is the distance from the homestead to nearest all weather road?	Actual distance in kilometres	
22. What is the distance from the homestead to the nearest KTDA Tea Buying centre?	Actual kilometres (*even if farmer does not currently supply KTDA*)	

3) **Tea Inputs, Output and Marketing Decisions**

Question	Indicator	Response
1. Is tea the main source of income for the household?	1=YES; 0= No	
2. What is the size of your tea farm?	1. Acres 2. Hectares 3. Number of Bushes	
3. How did your household acquire the tea bushes?	1=own establishment 2= inherited 3= purchased 98=other (specify)	
4. When was most of the tea planted?	*Year*	
5. What is the variety of tea in your farm?	0=Seedlings 1=Clonal 2= both	
6. How many times do you pluck your tea farm in a month	*Number of plucking rounds/Month*	
7. How many man-days are required for one complete plucking round?		
8. What is the source of labour for plucking?	1= family; 2= hired workers 3 = both = 98 other (specify)	
9. If hired labour is used, what is the payment arrangement?	1=daily wage *(indicate the rate e.gksh200/day*)	
	2= Kshs./kilo (*indicate the rate*)	
	3=Monthly casual *(indicate the rate*)	
	4= Labor exchange	
	98= Other (specify)	
10. Who takes your tea to the buying centre regularly? (*All that apply*)?	1= Farm owner/owner family 2= Farm employee 3= Neighbour/other nearby farmers 98= Other (specify)	
11. Did you apply fertilizer in your farm last season?	1 = yes 0 = No **>>13**	
12. If yes how many 50 kgs bags did you apply?	*No of bags*	
13. How many kgs of tea did you harvest last year (2015)?		
14. Which processing companies/factories do you supply leaf to? *(Multiple response*)	*Qualitative/open-ended*	
15. Which one of the companies/factories do you supply **MOST** of your leaf to (*if more than 1 in Q14*)?	*Qualitative (**one answer only**)/open-ended*	

Section B: Effects of Frost and Response

1) Frost Awareness, Effects Training and Mitigation

Question	Code	Response
1. What is the most serious weather-related problem that you face?	*1= Drought 2= Hail 3= Frost 4= Excessive rainfall/flooding 98= other (specify)*	
2. Is this area sometimes affected by frost?	*1=YES; 0= No*	
3. What generally is the frequency of occurrence of frost in this area?	*1= annual 2= after 2-5 years 3= after more than five years 4= no occurrence that I can remember of*	

Question	Code	Response
4. Can you sometimes know before it happens (frost) if there is going to be frost?	*1=YES* *0= No* ***>>7***	
5. If yes in Q4 above, how are you able to know?	1=Indigenous knowledge 2 = Experience as a farmer 3= information from other farmers 98 =other (specify)	
6. If yes in Q4 above (i.e. if you are able to know that there is going to be frost) on average how many days before occurrence /are you able to know (*typical lead time in which humans can detect upcoming disasters themselves)?*	1= at sundown the night of the frost 2= the morning before the frost 3= two days before, 98 = other (specify)	
7. Has your tea farm been affected by (some) frost in the recent past?	*1=YES* *0= No* ***>>34***	
8. If yes, was your farm affected this year (2016)?	*1=YES; 0= No* ***>>11***	
9. If yes, what portion of your farm was affected?	Actual acres/hectares Actual number of bushes	
10. For the portion of the farm that was affected, please indicate the number of bushes that suffered damage under the damage in these categories	Number Permanently damaged	
	a) *Stopped to produce for >3 months*	
	b) *Stopped to produce for 2 months*	
	c) *Stopped to produce for 1 month*	
	d) *Did not stop to produce but there was general decline in yield (specify the # of bushes and the % decline in yield)*	
11. Was your farm affected last year (2015)?	*1=YES; 0= No* ***>>14***	
12. If yes, what portion of your farm was affected?	Actual acres/hectares Actual number of bushes	
13. For the portion of the farm that was affected, please indicate the number of bushes that suffered damage under the damage in these categories.	a) Number Permanently damaged	
	b) *Stopped to produce for>3 months*	
	c) *Stopped to produce for 2 months*	
	d) *Stopped to produce for 1 month*	
	e) *Did not stop to produce but there was general decline in yield(specify the # of bushes and the % decline in yield)*	
14. (*If yes in Q7 but no in Q8 or Q11*)When was the most recent occurrence of frost on your farm?	*MM/yyyy*	
15. What portion of your farm was affected in time period in Q14 above?	1. Actual acres/hectares 2. Actual number of bushes	
16. For the portion of the farm that was affected, please indicate the number of bushes that suffered damage under the damage in these categories	a) Number Permanently damaged	
	b) *Stopped to produce for>3 months*	
	c) Stopped to produce for 2 months	
	d) *Stopped to produce for 1 month*	
	e) *Did not stop to produce but there was general decline in yield (specify the # of bushes and the % decline in yield)*	
17. When was the most severe occurrence of frost your farm has experienced?	MM/yyyy	
18. (*If 17 is not captured by 8, 11, or 14*), what portion of your farm was affected?	Actual acres/Actual number of bushes	

Question	Code	Response
19. For the portion of the farm that was affected, please indicate the number of bushes that suffered damage under the damage in these categories	*a)* Number Permanently damaged	
	b) *Stopped to produce for >3 months*	
	c) *Stopped to produce for 2 months*	
	d) *Stopped to produce for 1 month*	
	e) *Did not stop to produce but the was general decline in yield (specify the # of bushes and the % decline in yield)*	
20. Have you reported any of the frost incidents to any authorities or organizations?	*1=YES* *0= No*	
21. If yes, to whom?	*Qualitative/Open-ended*	
22. If no, why not?	*Qualitative/Open-ended*	
23. In the future would you be willing to report frost occurrence to your factory or any other organizations?	*1=YES* *0= No*	
24. Are you aware of any actions you can take to reduce crop loss if you know about a frost attack ahead of time?	*1=YES* *0= No*	
25. (If yes in Q24) Please identify the actions	*1=early harvest 2= skiving/skiffing 3= pruning 98= other (specify)*	
26. Have you ever tried any of the actions in Q25 above?	*1=YES; 0= No*	
27. If yes in Q26, which one(s)?	*1=early harvest 2= skiving/skiffing 3= pruning 98= other (specify)*	
28. If yes in Q26, what was the result?	*Qualitative/open-ended*	
29. If no (in Q26), why not?	*1= Not effective/would not have mattered 2=. Did not receive a warning 3= Received warning, but not enough time. 4= Not enough manpower 5= Too expensive/Cannot afford 98= other (specify)*	
30. When your tea farm suffered frost damage, what actions did you take immediately after the attack?	*1= skiving/skiffing2= pruning 3= Pursued other income* *98= other (specify)*	
31. What long term responses have you undertaken to respond to frost?	1. Planting shade trees 2. Replanted with a more frost resistant clone 3. Replacing tea with other crops in areas affected 98. Other (specify)	
32. Other than tea damage, did you suffer any other negative impacts of frost?	*1. Yes* *2. No*	
33. If yes in Q32, what other negative impacts of frost did you suffer?	*1= Loss of cattle 2= Loss of other crops 3= Loss of yield 4- Health impact 98= Other (specify)*	
34. Has any current member of your household received a training that included instruction on frost management?	*1=YES* *0= No* ***>> Part 2, Section B***	
35. If yes when was the most recent training?	MM/yyyy	
36. If yes in Q34, who organized the training?	1= KTDA 2= TRFK/TRI 3= MOA 4= KMS 5= Co-op/SACCO/Outgrower association 6= Other estate/factory 98= Other (specify)	

2) Potential of Frost preventive actions based on Early Warning System

Question	Code	Response
1. Do you own or have regular access to following communication items?	*iv. Radio 1=YES; 0= No*	
	v. Television 1=YES; 0= No	
	vi. Smart phone 1=YES; 0= No	
	vii. Mobile phone 1=YES; 0= No	
2. What would be the **best** way to communicate emergency information about frost to you?	*viii. 1= Radio 2= TV 3= SMS 4= Phone call 5= Extension officer 6= Tea Collection clerk 98= Other (specify)*	
3. If you have a mobile /smart phone, would you be willing to subscribe to an SMS service to receive information on frost?	ix. 1=YES x. 0= No	
4. If you receive emergency information on a likely frost attack, what is the likelihood that you will pass the warning to neighbours?	*xi. 1=very likely, 2= Likely, 3= Not sure, 4 = unlikely, 5 = Very Unlikely*	
5. If I tell you today that there will be a frost in three days, would you take any of the following actions?	*1. Early plucking 1=YES; 0= No*	
	2. Skiffing/skiving 1=YES; 0= No	
	3. Pruning 1=YES; 0= No	
	98. Other (specify)	
6. If I tell you today that there will be a frost in three days, how much of your ready-to-pluck tea would you be able to harvest before the frost?	*xii.* *xiii. 1= All 2= More than half 3= Half 4= Less than half*	
7. If I tell you today that there will be a frost in three days, what would prevent you from taking action to prevent losses? (*Multiple response*)	*1= No enough available labour , 2= No enough money to pay workers 3= Not familiar with preventive action strategies, 98 = other (specify)*	
8. If you received notice today that you would need additional labor tomorrow, would you be able to bring in additional workers on short notice?	*xiv. 1=YES* *xv. 0= No*	
9. If yes, how many?	*xvi.*	

Section (C): Household well-being and Expenditure

1) Information on household wealth indicators/conditions

a) **Housing conditions (*Main dwelling unit*)**; to be observed by enumerators. If they can't tell, or aren't sure, ask the respondent

What is the major construction of the material of the roof? 1=Thatch 2=Iron sheets; 3=Tiles; 98= Other (specify)		What is the major construction material of the external wall? 1 = Mud and poles; 2= Timber; 3= Burnt bricks/stone /blocks with cement; 98= Other (specify)		What is the major material of the floor? 1= Earth; 2 = Cement; 3= tile; 98= Other (specify)	

2) Households Assets

Which of these assets does your household own?	1 = Yes 2 = No	Approximate value[20] (*KShs.*)	Which of these assets does your household own?	1 = Yes 2 = No	Approximate value
Television			Motorcycle		
Radio			Wheelbarrow		
Mobile phone			cows (indicate No)		
Smart phone			No of chairs		
Bicycle			No of chicken		
Motor car			Others (specify)		

3) Information on Household Expenditure

	Expenditure items	**KShs.**
a)	In the last 7 days, how much money did your household spend on buying food items?	
b)	In the last 30 days, how much money did your household spent on non-food items? (*Including household items, medicines, school expenses, clothes, etc.* ***but excluding*** *unusual expenses such as wedding, surgery.*)	

Section D: Interviewer Debriefing: *(to be answered by the enumerator)*

E1	How do you judge the quality of the response based on the ability of the respondent to recall information and stay focused during the interview?	1. ☐ Very good 2. ☐ Good 3. ☐ Moderate 4. ☐ Poor quality
E2	Can you make any observations about the household or the interview that might be relevant for interpreting the data?	

[20] *If the asset were sold today, how much would be received for it?*

ANNEX B: FOREST FIRE SURVEY INSTRUMENT

Buen día, Usted ha sido contactado pues está incluido entre los usuarios profesionales de los productos de monitoreo de incendios forestales de CEMEC, incluyendo los mapas de puntos de calor. Nuestro objetivo es entender cuáles de los atributos de estos mapas tienen más valor para usted como usuario, para poder mejorar el servicio que se provee. Su participación es completamente voluntaria. Si usted desea terminarla en cualquier momento, puede hacerlo sin problema. Todas sus respuestas permanecerán confidenciales. En caso de tener alguna pregunta, por favor no dude en contactar a Jared Berenter o a Margarita Vides Irving.

El Sistema de Información Geoespacial para el Manejo de Incendios se refiere a un grupo de productos y servicios de monitoreo de los incendios forestales, principalmente utilizado en Petén. Estos productos y servicios son proveídos y administrados por el Centro de Monitoreo y Evaluación – CEMEC del Consejo Nacional de Áreas Protegidas. Actualmente los productos más conocidos son los mapas de puntos de calor, los cuales son distribuidos diariamente a las personas implicadas en las 14 municipalidades en Petén. Informes semanales correspondientes se distribuyen cada semana y al fin de la temporada de incendios.

1 Sector en el que usted trabaja:
- ❍ Gobierno (1)
- ❍ Municipalidades (2)
- ❍ Concesiones (3)
- ❍ Sector Privado (4)
- ❍ Instituciones Académicas (5)
- ❍ Organización No Gubernamental (ONG) (6)

2 Si usted se encuentra dentro de la Reserva de la Biosfera Maya, por favor indique la categoría de manejo dentro de la zonificación en la que se encuentra:
- ❍ Parque Nacional (1)
- ❍ Biotopo (2)
- ❍ Monumento Cultural (3)
- ❍ Reserva Municipal (4)
- ❍ Concesión Forestal (5)
- ❍ Zona de Usos Múltiples (6)
- ❍ Zona de Amortiguamiento (7)

3 ¿Cuál es su papel dentro de la organización? (Seleccione todos los que apliquen)
- ❑ Acciones de campo (1)
- ❑ Coordinación de acciones en campo (2)
- ❑ Toma de decisiones de acciones de campo a corto plazo (durante temporada) (3)
- ❑ Toma de decisiones anuales (antes de temporada) (4)

4 Durante la temporada de incendios, ¿Con qué frecuencia recibe los Puntos de Calor?
- ❍ En tiempo real (1)
- ❍ Diariamente (2)
- ❍ Semanalmente (3)
- ❍ No sabe (4)
- ❍ A pedido (5)
- ❍ Cuando se necesitan (6)
- ❍ De vez en cuando (7)

5 ¿Usted toma decisiones sobre el presupuesto en el puesto que ocupa actualmente?
- ❍ Sí (1)
- ❍ No (2)

Answer If Usted toma decisiones sobre el presupuesto en el puesto que ocupa actualmente? Sí Is Selected
6 ¿Cáda cuánto utiliza la información obtenida de los Puntos de Calor para informar la toma de decisiones de presupuesto?
- ❍ Diariamente (1)
- ❍ Semanalmente (2)
- ❍ Mensualmente (3)
- ❍ De acuerdo a la temporada de incendios (4)
- ❍ No sabe (5)

Answer If Usted toma decisiones sobre el presupuesto en el puesto que ocupa actualmente? Sí Is Selected
7 Generalmente la toma de decisiones de presupuesto se relacionan con (Seleccione todos los que apliquen):
- ❑ Dotación de personal (1)
- ❑ Equipo (2)
- ❑ Transporte (3)
- ❑ Suministros de campo (4)
- ❑ Ninguna de las anteriores (5)
- ❑ Otro (6) _____

8 ¿De qué manera utiliza la información de los Puntos de Calor? (Seleccione todos los que apliquen)
- ❍ Monitoreo de quemas agrícolas (2)
- ❍ Monitoreo de incendios ilícitos (3)
- ❍ Respuesta directa a los incendios descontrolados (11)
- ❍ Despacho diario de patrullajes (4)
- ❍ Planificación o distribución de fondos (5)
- ❍ Planificación o distribución de equipo (6)
- ❍ Planificación/despliegue de recursos humanos (7)
- ❍ Relaciones públicas (8)
- ❍ Para realizar objetivos académicos (1)
- ❍ La información no se usa (9)
- ❍ Otro (10) _____

A continuación, se le presentará una serie de opciones hipotéticas, puede ser que no estén disponibles, pero sus respuestas a pesar de ser sobre situaciones que no son reales en la actualidad, nos ayudarán a darle el valor que tienen las probables mejoras que se hagan. Por favor escoja la opción que sea la de mayor utilidad. (Es importante aclarar que los costos de los que se habla, también son hipotéticos y únicamente se están utilizando como medio de valoración, pero en ningún momento se está considerando el hacer cobros por los productos.)

9 **CARACTERÍSTICAS**	**OPCIÓN A**	**OPCIÓN B**	**OPCIÓN C (STATUS QUO)**
Frecuencia de distribución de los Puntos de Calor	Cada hora	Diariamente	Diariamente
Resolución espacial	50 metros	50 metros	1000 metros
Porcentaje de incendios no existentes en campo	1%	5%	20%
Inclusión diaria de pronóstico del tiempo	No	Si	No
Inclusión de biomas o sistemas ecológicos	Sí	No	No
Costos mensual	500 Q	300 Q	0 Q

- Opción A (1)
- Opción B (2)
- Opción C (Status Quo) (3)

10 ¿Cuál es su nivel de educación actual?
- Primaria (1)
- Secundaria (2)
- Técnico (3)
- Universitario (4)
- Maestría o doctorado (5)

11 En una escala de 1 a 10, en la que 1 es No tiene conocimiento y 5 es Experto, ¿Cómo calificaría su conocimiento de Sistemas de Información Geográfica SIG?
- 1 (1)
- 2 (2)
- 3 (3)
- 4 (4)
- 5 (15)

12 Género al que pertenece:
- Masculino (1)
- Femenino (2)

13 ¿Cuál es su edad?
- Edad (en años) (1) _____

Gracias por ayudarnos a evaluar los mapas de puntos de calor. Valoramos mucho su opinión. Por favor incluya cualquier comentario que tenga respecto a los productos. Todas sus respuestas permanecerán confidenciales.

ANNEX C: BIBLIOGRAPHY

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