GRP Kenya Project
Satellite Technologies, Innovative and Smart Financing for Food Security (SATISFy)

Section 1: Key Information and Solution Statement

1.1 Basic Project Data (1/2 page)

a. Title: Satellite Technologies, Innovative and Smart Financing for Food Security (SATISFy)
b. Region: Kenya (and scalable to Horn of Africa)
c. Lead Organization: International Food Policy Research Institute (IFPRI)
d. Target start date: October 1, 2016 Finish date: September 31, 2018
e. Any matching funds offered (provide brief explanation): No
f. Designated Problem Statement:

Uninsured risks are a major cause of low agricultural productivity in the Horn of Africa. In Kenya, four consecutive years (2008-2011) of drought amounted to US $12.1 billion in losses, including losses in assets and from disruptions in the economy flow across all sectors. Such severe shocks cannot be financed by the government and donor community alone. Moreover, lack of capital and perceived risks limit farmers' ability to purchase agricultural inputs and access credit, contributing to low agricultural productivity. While rural branches have grown 81% over the last five years and the M-Pesa mobile cash transfer service has increased by 1,000%, banks are still resistant to loan capitals in the agricultural sector. We propose a market-based, innovative risk management solution in the form of Risk-Contingent Credit (RCC), a social safety net that could mitigate drought risks for the rural poor and improve farm productivity and livelihood. RCC is a linked financial product that embeds within its structure insurance protection which, when triggered, offsets loan payments due to the lender. The triggering event is defined around the most significant risk that is highly covariate with farmer well-being, generally based on markets (price drops) or factors affecting crop yields (extreme weather events, such as drought) and sometimes both (i.e. when local prices are highly impacted by local production losses). In sub-Saharan Africa much of the risks faced by farmers are weather based and related to rainfall deficits.

From an economic point of view RCC resolves two major problems simultaneously. The first problem is that lenders are reluctant to lend to farmers because of the financial risks associated with crop failure or radical decreases in market prices. Because RCC targets downside business risk, it simultaneously reduces financial risk and exposure. This risk balancing effect will not only encourage increased supply of and access to credit but also will encourage risk-rationed farmers to increase the use of credit. Thus, by increasing financial depth, financial breadth, access and usage, RCC is a highly inclusive financial product.

The objective of our proposal is to design risk-contingent credit around a drought index with trigger points that are highly correlated with production losses in Kenya's wheat and maize sectors. This approach depends on the development of a satellite-derived drought index that integrates atmospheric- and land surface variables. We also propose the development of a mobile solution that facilitates the rapid and high-frequent assessment of local vulnerabilities and coping capacities to improve the knowledge base for emergency response and to validate the drought index. Our proposed research solution increases agricultural resilience by absorbing drought-related risk and shocks through innovative financing, stimulates agricultural productivity by increasing farmer access to credit, and increases livelihoods through market-based, but environmentally-determined solutions.

g. Please complete the attached chart for all team members:

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Section 2: Innovation and Impact Pathway

2.1. Solution Statement and Theory of Change (1 page)

At the core of SATISFy (SAtellite Technologies, Innovative and Smart Financing for Food security) lies the idea to battle chronic vulnerability with regard to crop failure and food insecurity in the Horn of Africa. The proposed solution starts on a high level of existing knowledge about financial mechanisms, socio-economic vulnerability and resilience towards climatic shocks. In addition, it acknowledges that such an endeavor is only possible with strong regional partners that guarantee the sustainability of outputs beyond the scope of the project.

Environmental data captured via mobile phone technology is foreseeably scalable in the Horn of Africa where SMS messaging is relatively common. This in turn can trigger positive changes in social welfare by decreasing uncertainties in decision making across different sectors. Consequently, we propose the development of a satellite-derived drought index that integrates environmental key variables (e.g. rainfall and soil moisture) based on state-of-the-art sensors and a corresponding mobile solution to relate the space-based information to actual conditions on the ground. The latter source of information is not only vital for farmers, but also for NGOs such as Doctors without Borders (MSF) in their operational needs in emergency response.

By far the most significant risks faced by Kenyan farmers depend upon the frequency and intensity of failure in long and/or short rains but these risks go largely uninsured. Uninsured risks are a major cause of low agricultural productivity throughout sub-Saharan Africa and limits access to credit by collateral-poor farmers. This in turn limits economic growth in the region. Our proposed research-based solution increases agricultural resilience in the Horn of Africa (Kenya) by absorbing drought-related financial risk and shocks through an emerging innovative financing tool that balances business and financial risks. Absorbing the burden of risk using risk-contingent credit (RCC) linked to a drought index will increase resilience and stimulate agricultural productivity by increasing farmer access to credit. In addition, it will improve livelihoods through market-based, but environmentally-determined solutions.

Because the insurance component of RCC substitutes for collateral, it is more financially inclusive than conventional credit products. Thus RCC can bring risk-rationed farmers (who tend not to borrow or borrow less than is optimal for fear of losing collateral and falling into a credit-driven poverty trap) into the credit market. SATISFy aims to include private sector partners, such as Equity Bank Kenya, to implement this market-based solution in order to provide smallholder farmers with access to credit and stimulate investment in the agriculture sector. Below we provide a brief description of RCC and how it can protect farmers from adverse weather and climate shocks, such as drought.

The general RCC mechanism is depicted in Figure 1 where upper graph shows loan repayment and lower graph represents underlying option (insurance) payout. The horizontal axis captures the major weather risk as measured by the drought index; low values are highly correlated with production loss (we include commodity price to illustrate the scalability of RCC to other sources of risk). The threshold, or insurance trigger, will usually be economically linked to a particular outcome that will smooth consumption in extremely bad conditions. If the underlying risk (drought) increases and crosses a certain threshold, the total loan repayment obligation of a farmer falls linearly as drought conditions worsen. In practice, however, the payoff function might be highly nonlinear. On the other hand, if the underlying risk increases beyond the threshold the loan has to be repaid by the farmer, including the risk-contingent interest rate which will be higher than interest rates on conventional collateral loans. Risk-contingent credit has therefore the unique characteristic that even though farmers have to pay a risk premium during normal circumstances, they are insured against adverse circumstances. RCC is designed with an actuarially fair interest rate that is interlinked with the underlying drought risk.

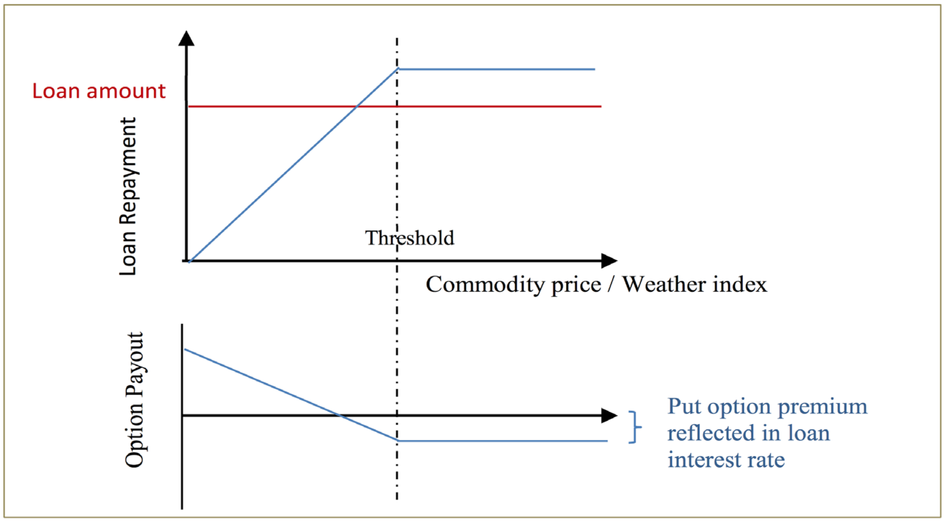

Figure 1: Schematic Illustration of Risk-Contingency Credit (RCC)

2.2. Impact Pathway Diagram (1 page)

Producing a series of datasets via high-quality research is considered important, but not enough to meet the targets of SATISFy. In order to achieve the strategic objectives of the Global Resilience Challenge, we must also ensure that those outputs are used by a range of key stakeholders, whose actions will, in turn, have an impact on improving the lives of millions of poor people. Designing the impact evaluation (Fig. 2) requires answering the main question and understanding the steps in the results chain.

	Impact Pathway				
Needs	Input ⇒	Output ⇒	Outcome ⇒	Impact	Long-term Development
Farmers in Kenya face drought risks and are credit-constrained; Farmers need innovative financing to create social safety nets; The knowledge base for complementary emergency response needs to be improved	Satellite-derived combined drought index Information about markets and vulnerabilties/ coping capacities on household level	Risk Contingent Credit designed and implemented in collaboration with private sector Drought warning accessible to farmers, decision-makers, aid organizations	Increased investment in smallholder maize and wheat production at lower production risk	Increased household income and welfare due to existence of sustainable social safety net Increased coping capacities with respect to climatic shocks	Increased resilience for smallholder farmers Decreased need for external assistance (emergency response)

Figure 2: SATISFy Impact Pathway Diagram

The question here is: Does RCC improve the production strategies and welfare of smallholder maize and wheat farmers? The impact pathway diagram links actual needs to inputs, expected outputs, outcomes and long-term impacts. As a consequence, the chain starts with the need or the problem, which is adverse weather (drought) and limited access to credit. This creates the need of a risk transfer mechanism. We use a new satellite-derived combined drought indicator and household/market information collected via mobile technologies to design the RCC. Subsequently, RCC increases investment in smallholder maize and wheat production, resulting in a positive effect on household income and reduces the need for emergency response in case of a climatic shock.

In the long-run the proposed pathway has the potential to reduce chronic vulnerability and increase disaster resilience for smallholder farmers in Kenya.

2.3. Innovation and Impact (1 page)

Through innovative approaches and technologies, this project proposes to build resilience in the Horn of Africa (Kenya) despite frequent droughts, and in turn stimulate a ripple effect of increasing agricultural investment, productivity, and farmer livelihood and welfare. Our scalable solution combines unique approaches that includes the development of a RCC scheme between local banks and farmer communities, and a high-quality drought index, all connected through a weather-driven mobile solution. The underlying data driving the drought index are geographically specific and reflective of local, current conditions, based on high resolution satellite imagery, mathematical models, and ground truthing. The drought index, therefore, is designed to communicate with emergency response systems via mobile phones and trigger a series of RCC-mobilizing events between banks and farmers. There are at least three innovations in this project:

1. **Development of a quality drought index.** There are several drought indices that are fed with satellite-derived data. Most of them focus on rainfall measurements that tend to be inaccurate over large parts of East Africa. Measurements of vegetation health are valuable estimators of agricultural conditions, but they are not suitable for early season applications and only partly transferable to estimates of actual yield. To date, hardly any index considers soil moisture, one of the more recent operational satellite datasets, despite its importance for quantifying the severity of agricultural droughts. However, in the face of little knowledge about robust temporal relationships between surface and root-zone soil moisture deficits and related anomalies in vegetation health and crop yield (Gouveia et al. 2009; Zribi et al. 2010), it is vital to identify the added-value of soil moisture for operational decision-making. Recent multi-million satellite missions are already providing measurements at far higher spatial resolutions than before (up to one kilometer and higher). In combination with already operational space-based sensors, they allow global coverage at high spatial and temporal resolutions.
2. **Development of a smartphone app and corresponding database for the collection and sharing of additional socio-economic information.** Traditional crop and food security assessments take four to eight months, causing severe problems to the logistics of aid organizations in the case of General Food Distribution. Based on the requirements of MSF, SATISFy aims at the development of a mobile application for smart phones. Initial tests carried out by Vienna University of Technology and MSF in the Central African Republic showed that only one day of training is needed to get local Community Health Workers ready for food security assessments. These assessments are carried out weekly or bi-weekly and focus on issues related to the number of meals per household, the prevalence of oedema in children between 6 and 59 months, their mid-upper arm circumference, the household's diet, etc. Once recorded, including GPS location, each assessment is stored on the phone and automatically uploaded once a network is in reach. Different aid organizations can then use the information for improved decision-making. The app can easily be adapted for the needs of Kenyan farmers, including questions related to agricultural production, delays in the start of the season, etc.
3. **Drought risk management via financial instruments: Risk-Contingent Credit (RCC).** RCC is an innovative financial instrument that can be designed using remotely sensed biophysical data. With the efficient development of a drought index mentioned above, we can reduce design related basis risk in RCC. Improved access to credit by farmers and downside risk management through RCC can alleviate many production constraints in the short term and encourage technology adoption and growth in the long term. Since RCC embeds an insurance component that mitigates risks in agriculture, supporting production at times of negative shocks can promote resilience among farmers. Lenders will reduce (or eliminate) collateral requirements, thus increasing demand by poor and risk-rationed smallholders farmers. And because credit is interlinked with agricultural production risks, loan default risk is reduced significantly.

2.4. Outcomes (1 page)

We define the window of opportunity along three areas: Remote sensing and GIS, an innovative financial product, and mobile technology to reach out to the last mile (Figure 3). While each dimension can function independently, the opportunities of this call lie in the intersection (Area 4).

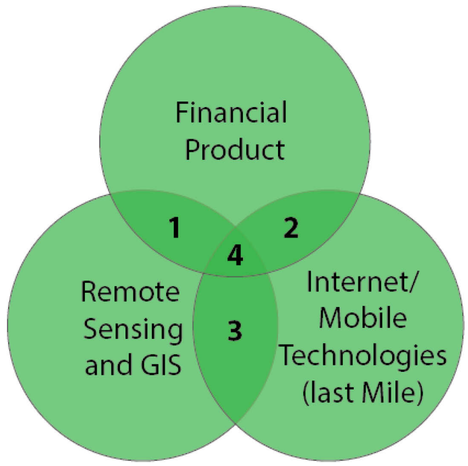

Figure 3: Dimension Defining the Window of Opportunity

Remote sensing and GIS - Financial product (Area 1): The application of state-of-the-art remote sensing technology in the index insurance sector has gained considerable interest and attention in recent years. Insurance alone is not enough to spur economic growth in poor communities, but rather an innovative financial product is needed that not only manages the risks communities face, but also provides access to credit to invest in their livelihoods. The development of an RCC scheme can only be successful if the required satellite-derived information is (continuously) available and well validated via records of yield, food insecurity, etc. Only then will the satellite component result in an actual added-value for decision-making. In addition to conventional satellite data, SATISFy relies on an entire new product that was recently developed by Vienna University of Technology to combine different space-based sensors to achieve the best data quality for soil moisture on global scale.

Financial product - Internet/Mobile technologies (Area 2): Mobile technology in the Horn of Africa has revolutionized how financial transactions are taking place and how companies can reach out to the last mile. In October 2014 the number of active mobile devices exceeded the world population. In sub-Saharan Africa alone, the market is expected to grow from 635 million subscriptions in late 2014 to 930 million by 2019 – double the growth rate compared to the rest of the world (Ericsson, 2014). This development improves people's ability to operate smartphones, increases the extent of mobile phone networks and provides a better framework for new applications, such as food security assessments. This project aims to invest in new ways of mutual information exchange between data/insurance providers and users, creating a vital feedback loop.

Remote sensing and GIS - Internet/mobile technologies (Area 3): Combining remote sensing and GIS technologies that directly reach out to the last mile is becoming a reality. The use of internet and mobile phones to collect, validate and distribute data is gathering popularity and social acceptance. These approaches and technologies can be adapted to collect and distribute vital information from and to societies at risk.

The business case (Area 4): The business model brings all the three above mentioned areas together. It aims at the implementation in collaboration with users and at upscaling, if evaluated as successful by the users. Although challenging, this provides the crucial platform to innovate the linkages between research, technologies and business.

2.5. Next Users and Use (2 pages)

There has been an emerging cooperation between commercial insurance industry and remote sensing community in recent years. The application of remote sensing in index insurance sector has gained considerable interest because the remote sensing indices can not only be constructed to correlate well with insured crop losses and delivered at lower cost, but can also open up new markets that are not served by traditional insurance. We are particularly interested in integrating index insurance with credit repayment structure to provide credit and manage weather risks faced by otherwise vulnerable farmers in the Horn of Africa. With the insurance component embedded in the credit product, lenders will reduce (or eliminate) collateral requirements, thus increasing demand by poor and risk-rationed smallholders farmers. It also eliminates the drawbacks of standalone index insurance products by not requiring the farmers to pay upfront. With this arrangement we expect high uptake of RCC by Kenyan farmers with significant and consequential impacts on various outcomes.

To capture this causal relationship, we will employ a randomized control trial with baseline and end-line data collection. In Figure 4 we provide a network map of key actors where the composite indexes created by the remote sensors (RS) are used by financial economists and statisticians to establish a statistical relation between RS indexes and crop yield. From these relationships RCC risk premiums and interest rates will be calculated using actuarial methods. A private sector financial institution (Equity Bank) will then deliver RCC to maize and wheat farmers with a suitable RCC contract. After adopting, farmers will then provide feedback to the research team to further improve the design. The research team will also set up a controlled experiment to capture causal relationships between outputs and outcomes. The demand for project's outputs will come from not only the research community but also from private sector partners.

The indemnity from the insurance is applied to the underlying debt obligation or debt service, thereby reducing the probability of default on loans by producers, improving risk bearing ability, enhancing the supply of credit, and facilitating investment and development. Due to the nature of the agricultural and financial infrastructure in Kenya, producers are typically unable to access or replicate these types of risk management tools themselves, whereas financial institutions are in a much more natural position to provide contingencies for and bear such risks. Specifically, the lender is in a natural position to aggregate and manage these risks for pools of producers and can also more easily access global financial and reinsurance markets (e.g., our partner, SwissRe) to hedge the resulting risk in their portfolios arising from the risk-contingent loan contracts. We believe risk-contingent credit structures could provide the proper incentives to entice banks (e.g. Equity Bank) to increase the supply of credit to pastoral households. We also expect financial relationships with insurers and regulators would be required for product delivery. In this regard, we plan to influence the Government of Kenya task force on National Agricultural Insurance Policy. In terms of financial education and outreach, we plan to work with local NGOs and farmers groups (such as SACCOs). Since partnerships with implementation organizations with strong ground network are important in the pilot phase we plan to involve local NGOs for outreach and product marketing.

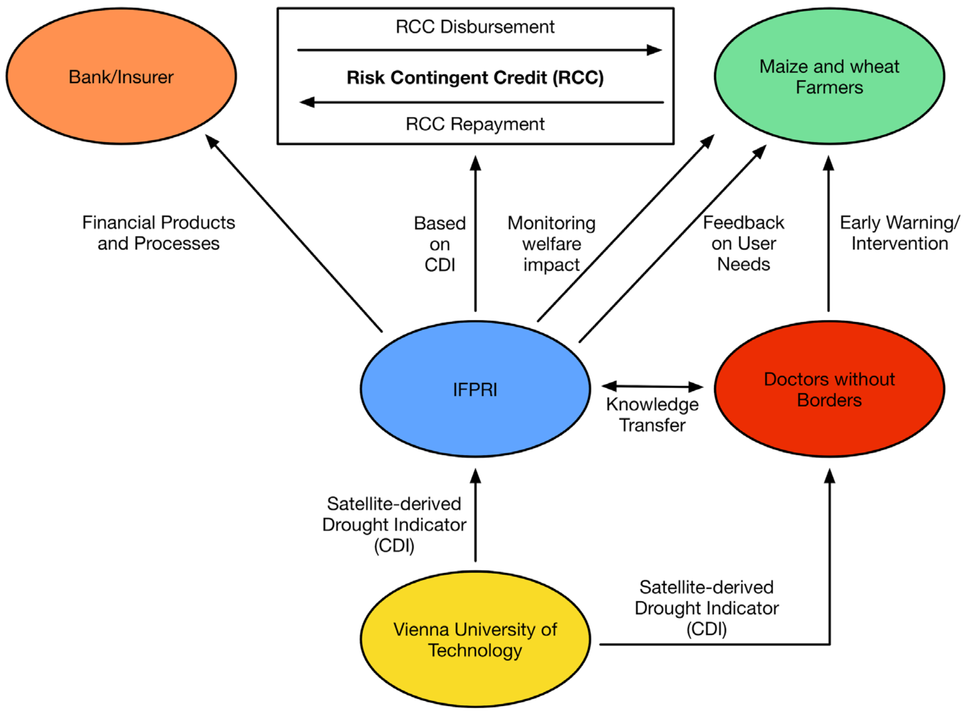

Figure 4: Network map of key actors

MSF explicitly expressed the need to complement traditional crop and food security assessments by higher frequency assessments. Usually, such assessments are carried out by the United Nations, World Food Program, and FAO. Their completion usually takes four to eight months, resulting in an enormous time loss for disaster preparedness. As a consequence, our crowd-sourcing (or group-sourcing) approach will take advantage of local partners in vulnerable or already affected regions. A new GPS-based smartphone application will be developed based on open source software. The app can easily be adapted for changes in local conditions or for the validation of satellite-derived datasets via low-cost Bluetooth sensors, and it will be based on a set of simple quantitative questions, providing information that satellites or gauges cannot capture. The questions will cover socioeconomics, health (such as malnutrition among children; prevalence of major diseases), availability and access to food and water, institutional capacity and coping mechanisms. The team is already experienced in conducting both full-fledged multi-topic household surveys and SMS-based surveys in rural developing settings in Africa. Through the smartphone application, researchers will have the opportunity to analyze the impact of medium- to large-scale drought phenomena on the landscape (e. g. at the district level). Moreover, MSF will use, analyze and share the collected information for operational planning, such as logistical preparations.

2.6. Outputs (1 page)

Our two main research components are: 1) The development of a drought index using satellite-derived information on rainfall, vegetation health, temperature and soil moisture as an input; and 2) Building institutions and services to improve market effectiveness and disaster resilience. We plan to complete at least two publications, focusing on the capability of the latest satellite-derived drought indicators to reflect drought impacts on the ground (paper #1) and their use for the development/adaptation of RCC schemes (paper #2).

Output 1: Development of improved drought index to support RCC design. Our main focus will be to make RCC more attractive and accessible for farmers due to improvements of the index design via new satellite-derived datasets, which enable reducing the basis risk. We plan to exploit the statistical relationships between remote sensing indexes and yield distribution of maize and wheat production to design actuarially fair premium structures for RCC. Apart from weather, other factors might necessitate the requirement of collateral for risk contingent loan. This is where MSF comes in to relate the satellite-derived information to impacts on the ground via local assessments that they can use as well for early warning. As a consequence the main outputs will be the design of the combined drought index, a database to record and analyze assessments carried out via mobile technologies, and the related insurance scheme including premium structures of the RCC.

Output 2: Building institutions and services to improve market effectiveness and disaster resilience. Institutions and services are important to deliver risk management options for the farmers, but also to support a paradigm change from emergency response to early warning. The risk management options concentrate on research-based financial products in combination with building capacity along the market development and implementation chain. Our financial partner in the private sector, the Kenyan Equity Bank (largest commercial bank in Kenya), has a wide outreach in rural Kenya. Additional support from SwissRe, our commercial reinsurance partner, will enable randomized control trials of the new RCC design. These control trials will be carried out with the best possible background knowledge and coverage. In parallel, we aim to stimulate RCC feedback and, if successful, demand by providing targeted marketing. Upscaling and possible RCC extensions will be supported by local staff of all project partners, as well as related news and policy briefs.

Output 3: Behavioral change, policy and impact assessment. A rigorous research program is necessary for a comprehensive understanding of impacts and associated policies for our risk management and innovative financing intervention. Though our baseline survey, randomized control trial design, and end-line survey data collection, we plan to capture economic and behavioral changes amongst beneficiary farmers. This will be the basis for scaling up the risk financing initiative to other regions of Africa, supporting the sustainable intensification of agriculture. Moreover, this approach will also allow us to make recommendations for the use of public resources to improve drought response and resilience via semi-annual policy briefs directed at decision-makers on all management levels (local, regional, national). Through an innovative and efficient data collection method, we will be able to test various hypothesis on behavioral change among farmers. We aim to develop a corresponding database that allows the download of collected data in standard formats (e. g. readable by MS Excel) and a public web-portal to display all relevant drought information. Also planned is the generation of overlays for Google Earth that enables users to display maps in a few clicks.

Output 4: Knowledge transfer and capacity building. Linking RCC to active partners in early warning and emergency response can lead to more comprehensive risk management. If successful, SATISFy has the potential to enable investment in yield enhancing, sustainable intensification initiatives in the Horn of Africa. Consequently, we include knowledge transfer and capacity building related to agricultural productivity, access to finance, climate change and sustainable intensification of climate smart agriculture.

2.7. Workplan and Timeline (2 pages)

We have selected two main agricultural crops (maize and wheat) grown by smallholder farmers in our focus area in Kenya. We look at this research effort as the gateway to piloting risk-contingent credit in other areas throughout Horn of Africa and beyond.

In the first stage of investigation we will lay the groundwork through farm household interviews, meetings with agricultural lenders and insurers, and the collection of baseline credit information and through a series of field experiments to determine farmers' demand for RCC, their willingness to pay for RCC and the household demand elasticity for credit. During this stage we will also develop a composite drought index using various remotely-sensed weather and ground information such as vegetation, precipitation, soil moisture, etc. After developing a high quality drought index we will do a statistical response function estimation using maize and wheat yield information from the surveys. And ultimately we develop RCC pricing using actuarially fair pricing mechanism with drought index.

In the 2nd stage of the project we will be implementing with local lenders and insurers a randomized control trial of RCC with maize and wheat farmers. The 2nd stage will end with final survey data collection of various socio-economic variables.

Phase I: Design of composite drought indexes and RCC premium estimation

Phase I will also include the determination of risk premiums in interest rates for price insurance according to the formula discussed in methodology section. Conventional tests for a geometric Brownian motion will be conducted on drought index developed using various remote sensing indexes. If prices are found to be fractional, rather than Brownian, then pricing techniques based on autoregressive Monte Carlo simulations will be developed to determine the maize and wheat price option premium.

Phase II: Randomized Control Trials and information dissemination using mobile technology

In Phase II we intend to obtain support from a local agricultural lender and insurance company to make risk contingent micro-credit loans. State of the art procedures using randomized control trials are planned. From Phase I results we will have basic information on (potential) borrowers in terms of the amount of loan required with and without the risk contingency, the rate of interest they are willing to pay for this loan, and other critical items such as whether they are risk, price or credit rationed. The field loan trials will be done in second year and will be repeated in the 2nd year of Phase II.

2.8. Questions and Methodologies (3/4 page)

The principal objective of this proposal is to promote efficient drought management through remotely sensed data of the Earth's surface and to evaluate and work with local stakeholders in Kenya to develop financial innovations directed towards building resilience for smallholder maize and wheat production and farmers in Kenya. The central question of innovative financing is whether risk-contingent credit can positively impact not only the supply of credit to farm households but demand as well. In answering this fundamental question several questions must also be resolved including: a) whether price or risk-rationed farm households are more likely to efficiently use credit if it is coupled with 'insurance'; b) whether farm households have a demand for risk contingent credit; c) how much extra in interest rate (a risk premium) are farmers willing to pay for insurance; d) how would risk-contingent credit affect overall welfare by improving farm productivity, household consumption, and savings etc.; e) to what extent would a rural lender be willing to partner with an insurer or counterparty to retail risk-contingent credit to farm households; f) to what extent would a rural lender be willing to increase supply and/or reduce credit rationing if risk-contingent credit were made available; g) what type of banking and insurance regulatory and oversight policy would be required to ensure that risk-contingent credit is issued on a sound basis; and h) what type of risk-layering insurance/reinsurance structure might be required.

Designing an RCC product will involve the calculation of actuarial options/insurance premiums included directly into the credit formulas for risk-contingent loans. Our method is to explicitly determine the risk-adjusted interest rate premium above the base interest rate of a collateralized loan that reflects the expected value of the indemnified risk. In this respect, we assume that the lender is indifferent between receiving the present value of an operating loan, f, at market interests rate r^{**} and a risk-contingent operating loan with an embedded option at an interest rate r^{*}. The interest rate, therefore, is the rate that would make the lender indifferent between an operating loan with the linked weather option and one without the option. Assuming a hedge ratio ψ, strike price K_W and loan length T, the interest rate will be calculated as:

$$r^{*} = \frac{\ln\left[\frac{\psi E\left[Max\left(0, K_W - W(t)\right)\right]}{f} + e^{\left(r^{**}\right)T}\right]}{T}, \text{ with } \quad r^{*} > r^{**} > r \text{ and, } \quad \psi = \frac{f}{K_W}$$

Drought and weather-related information, such as satellite-derived measurements of rainfall, soil moisture and vegetation, can be used to measure weather risks faced by farmers in different parts of the season. This requires sophisticated methods to identify the temporal lags between anomalies in rainfall, soil moisture and evapotranspiration and vegetation health in order to combine all variables in one satellite-derived indicator. The general method to establish corresponding drought warning levels is based on historic reports about drought impacts (e. g. crop failure, food insecurity) and the assessment of critical thresholds based on the standard deviations of the combined drought indicator. In order to increase the user-friendliness all datasets will be average per average unit, allowing the illustration of dekadal drought conditions as images and as time series per each grid point.

2.9. Measuring Progress towards Outcomes

Monitoring and evaluation of SATISFy will be crucial to support effective project management, provide data for timely reporting, and help all stakeholders to learn about project successes and failures. A robust M&E system that provides learning opportunities on what has worked and what has not will in turn inform the project implementation, as well as catalyze adjustments to ongoing activities that might enhance efficiency and effectiveness. SATISFy is committed to achieving a number of specific goals in terms of its deliverables and approach:

- International standards compliance**:** The M&E activities will conform to the overarching M&E standards, best practices, and core indicators established for this type of initiative.

- Open-access platform**:** The M&E activities will deliver and maintain an open-access, transparent M&E data management and analysis platform to serve the needs of scientists and other stakeholders. Open data access is now mandated by both US Government regulations and the CGIAR Consortium, of which IFPRI is one of the network institutions.
- Multi-scale reporting**:** To meet different stakeholder needs, and to provide the capability to support multi-scale monitoring and evaluation, the M&E platform will be designed to report at several scales and levels of aggregation.

Measuring and monitoring progress will be embedded into this project from the onset. Through the mobile network technology, information on environmental indicators from remote sensing data will be distributed and shared among the project's actors since the indicators' value will be the basis on which RCC is offered to farmers. In this respect, a transparent and reliable system will be set-up and deployed using the mobile network.

The use of the mobile technology will not be limited to downstream information from remote sensing to farmers, but also to upstream information from the latter to the project's implementers. Through short SMS-based surveys, this would also allow us to monitor and evaluate the impact of the project on a variety of outcome indicators. Information collected through the mobile application will be complemented by more traditional household surveys, using a randomized controlled trial approach.

To test the hypothesis that SATISFy leads to improved resilience and development outcomes, one would need to answer the counterfactual question of "how would farmers' resilience and development outcomes have fared for farmers who are offered (and accepted) the innovative financial products in the absence of them?". Since it is impossible to know the answer to this question, one needs to establish a credible group of farmers who would have had characteristics (risk aversion, welfare, creditworthiness, etc.) similar to those who were exposed to the products but who did not choose them. The specific approach to be pursued for testing the above hypothesis will be guided by the scale, nature, and timing of (planned) adoption of the RCC, especially since site- and context-specificity and own-adaptation by beneficiaries are integral parts of the project. Randomized control trials (RCTs) have progressively become the standard way by which the impacts of a new intervention can be assessed, and they can also be applied in the context of SATISFy, taking the self-selection of farmers who will choose the RCC into adequate account in the impact assessment analysis.

To accurately estimate the extent to which changes in outputs and outcomes of interest can be attributed to SATISFy, the team will be designing and implementing an evaluation strategy that ensures robust measurement of these economic phenomena. A carefully designed impact evaluation is also necessary for well-informed decisions about future enhancements. Unlike project monitoring, which examines and tracks whether targets have been achieved, impact assessment examines how outcomes of SATISFy beneficiaries have changed as a direct (and, if modelled explicitly, indirect) effect of the project. It seeks to provide cause-and-effect evidence and quantifies changes in (development) outcomes that are *directly or indirectly attributable* to the project, and not to other confounding factors. When there is a non-random selection of target communities and households, various non-experimental designs could be explored to construct a plausible counterfactual group. For example, if selection determinants are known (or believed to be observable), then various regression-based approaches (e.g., matching) can be employed to construct an acceptable comparison group and mitigate selection bias. If selection determinants are (believed to be) unobserved but are thought to be time invariant, panel data approaches (including simple differences-in-differences) can be employed. When none of the above is possible, the problem of selection bias cannot be addressed and any "impact evaluation" effort will have to rely heavily on the program theory. It should also be noted that the internal validity of the causal evidence will depend on the quality of the match between target and comparison groups, while the external validity of the results will depend on the representativeness of the sample from which the evidence is drawn.

Irrespective of the specific evaluation design, however, target households and communities will need to be statistically representative within the area of interest. Representativeness is necessary (but not sufficient) to ensure external validity of results and assist in informed decision making.

In addition, RCC would need to be chosen by a sufficient number of farmers to precisely estimate its effect. The team will provide a predictive assessment on the likely take-up of the product, to be subsequently able to obtain an adequately powered sample for impact evaluation. In the absence of a credible and thoughtful evaluation approach, estimates of the effect of SATISFy on resilience and development outcomes will be inaccurate and imprecise and, therefore, cannot be extrapolated.

2.9.1. Indicators

Below is a graphical representation of the components necessary for an effective information system for resilience impact analysis, diagnostics and decision making.

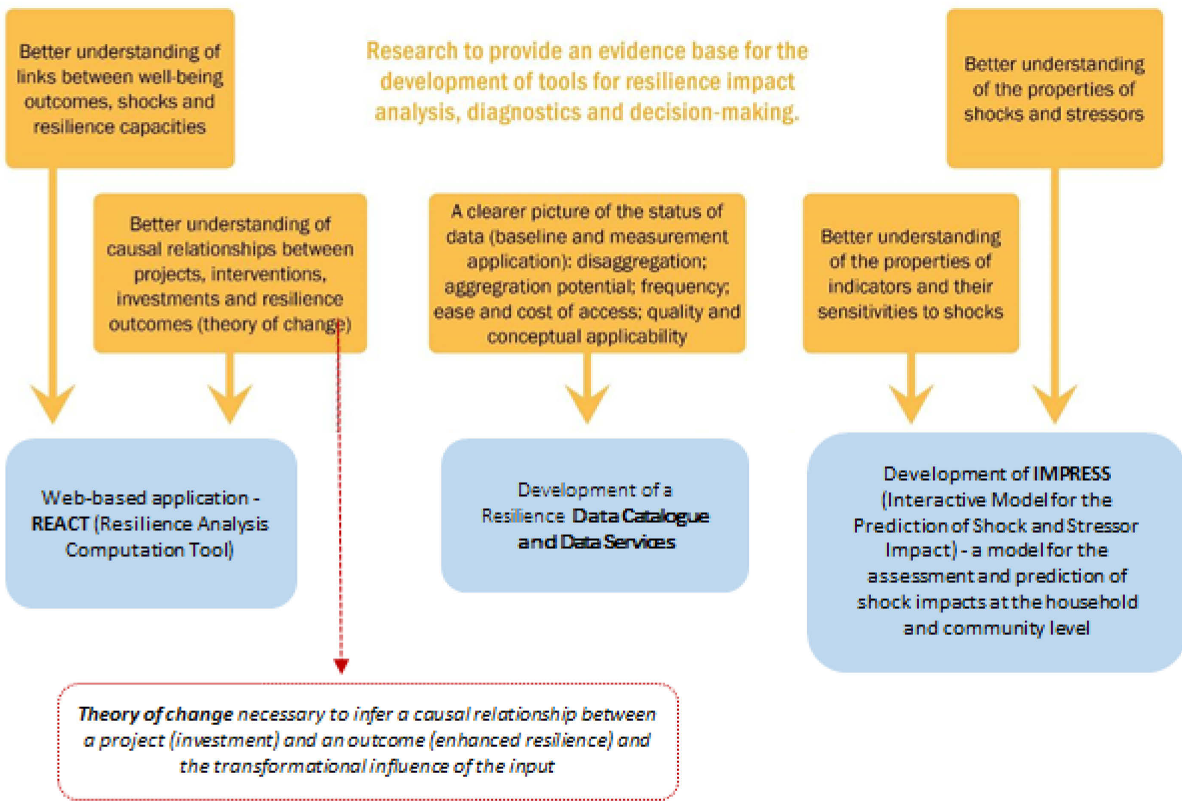

Figure 5: Components of Resilience Impact Analysis

In addition to data collected among farmers who will choose RCC to estimate the direct effect of SATISFy, the team will measure potential indirect effects of the project to understand the transmission mechanisms and gain insights on how the project operates. To this end, careful thought will be given to data requirements for correctly measuring spillovers within the context of the project (Angelucci and Di Maro, 2010). (Spillover refers to a situation where farmers not eligible to receive intervention, or who are eligible to receive the intervention but have not received it, benefit from the intervention indirectly through a variety of ways – such as externalities, general equilibrium effects, social and economic interactions, and behavioral changes.) The purpose of data collection from non-beneficiary farmers in sites where RCC will be offered will be to measure spillover effect from project activities. Besides data collected through traditional face-to-face interviews, new data collection methods will be employed, taking advantage of the mobile technology system set-up.

2.9.2. Baseline

The team will collect detailed and exhaustive household and community baseline data, to capture the baseline characteristics of both beneficiary and control households and communities. To assess risk behavior and trajectories for different household typologies as they occur, and to inform the development of scaling up and out strategies, data need to be collected on composition of households, credit behavior, agricultural activity, livestock systems, farm and crop management practices, use of inputs, and key livelihood strategies employed, all dimensions that the survey instrument can capture. These are crucial data to evaluate risk aversion and to study the correlates of RCC adoption over time. Using baseline data together with mid-line and end-line data would allow the comparison of various socio-economic and environmental outcomes of interest among beneficiaries, non-beneficiaries, and control households through multivariate regression analysis (e.g., matching).

2.9.3. Provide a Monitoring and Evaluation Plan (M&E)

Our M&E Plan will consist of three separate but interconnected components:

1. A data information system that will use the mobile technology and network in both a top-down and bottom-up mode. The exchange and sharing of information will occur from the data hub collecting information through remote sensing to farmers, and from the latter to the project implementers, on specific economic dimensions.
2. SMS-based surveys, which will serve the scope of a quick data collection in between traditional surveys periods, to gauge the dynamics of specific indicators (i.e. up-take of RCC, eventual temporary credit constraints)
3. Periodic traditional household surveys, conducted at three points in time as a minimum. They would allow a carefully solid, quantitative impact evaluation using a difference-in-difference ((before-after)-(treated-control)) approach in the context of randomized controlled trial with three groups (beneficiaries, non-beneficiaries, controls).

The M&E plan will be revised on an annual basis, to take account of the experience of the project and its implementation on the ground to enhance flexibility and adaptation to ever-changing circumstances.

2.9.4. Provide a Value for Money Plan

Empirical evidence on the benefits of improved resilience through financial products remains in short supply on topics such as determinants of take-up within heterogeneous populations and adoption dynamics. There is also limited evidence on the role of wealth, education, market access, information asymmetries, individual preferences, and risk aversion on farmers' willingness to adopt. The resources and the considerable effort that the team will pour into the planning and implementation of the monitoring and evaluation system is in an attempt to provide the strongest empirical evidence possible. Also, the reliance on costs and benefits specific to RCC will guarantee a rigorous value for money through quantitative cost-benefit analysis. Outcomes and expected impact pathway we expect from SATISFy are identification of alternative options to alleviate credit constraints and enhance technology adoption (e.g. climate-smart agricultural practices) and subsequent benefits thereof for improved farmer's resilience.

Section 3: Achieving the Resilience Challenge

3.1. Gender and Equity (3/4 page)

Women play an important role in drought management of developing countries. They are mostly responsible for agriculture and water supply. Hence they possess valuable traditional knowledge. The project team recognizes that they must not be neglected in knowledge transfer and drought management. Gender differences and inequalities would be integrated into the consortium activities and project design and into criteria used to evaluate the success of this project. A gender analysis would discuss important gender issues relevant to the usage of satellite and mobile technologies as well as the adoption of risk contingent credit. The various activities in this project would explicitly explain how gender considerations and equality issues will be integrated into the design, implementation, management, knowledge sharing, capacity building, and monitoring and evaluation of the overall project activities.

3.2. Resilience (3/4 page)

This proposal cuts across several themes but most central is the inter-linkage between instruments for risk management and resilience and measuring and disseminating drought information. We not only build farmers' resilience by managing drought risks in vulnerable prone areas, but also provide financial protection and capital for agriculture. This research will build resilience by reducing downside risks faced by farmers and by building capacity of farming communities. Indeed, our innovation is a financial product embedding an insurance component that mitigates risks in agriculture, supporting production at times of negative shocks. The aim is also that, with the insurance component embedded in the credit product, lenders will reduce (or eliminate) collateral requirements, thus increasing demand by poor and risk-rationed smallholders farmers.

Also, research has shown that credit demand becomes less inelastic with lower risks so farmers previously price rationed due to risk would likely increase their demand, thus leading to efficiencies in production, consumption and savings. Likewise, with the insurance component in place lenders face reduced risk of loan performance and will increase loans at lower rates to a clientele previously avoided.

While we have developed the various mathematical structures for risk contingent credit, the next phase addressed in this proposal is to put forth the necessary field work to identify the risks, assess demand, and enumerate willingness to pay. This latter part is critical since risk contingent credit requires an enhanced premium. It is critical to that farmers can understand the payoff structure that warrants this premium. Only when this work is done will a randomized control trial making actual microloans to maize and wheat farmers be viable. In terms of financial institutions we view any financial innovation that simultaneously balances business and financial risk to be demand and supply enhancing. Even in the absence of any form of subsidy the potential to increase the credit elasticity of both supply and demand will be welfare enhancing.

3.3. Sustainability (1/2) page

Considering the huge volume of economic losses due to drought in the Horn of Africa and Sahel region, we propose a market-based solution to deal with economic loss incurred by drought occurrences. Instead of disaster risk management and relief, we emphasize an innovative financial protection mechanism for smallholder farmers that will be sustainably implemented by local private sector partners. A typical small scale maize or wheat farmer requires credit of approximately 40,000 KSH ($470) for land preparation, fertilizer, seed, and sometime labor. During the long-rain season starting in March most farmers need credit but during harvest time in Oct/Nov maize prices can become very low and many farmers face distress sales to local traders. Although the National Cereals and Produce Board of Kenya provides some relief, the long time to pay farmers creates a liquidity trap. Thus, interventions using risk-contingent credit can be of great sustainable benefit for maize and wheat farmers.

Section 4: Risk Management

4.1. Risk Matrix (1 page)

We see no risks in Phase I research, but there are substantial uncertainties about the RCTs in Phase II. In particular we have no firm commitment from financial institutions to provide the financial backing of the RCTs. To obtain such agreements before proof of concept at the Phase I stage is difficult. The usual procedure for RCT of this type is to ensure that the participating lenders and insurers are no worse off by participating than they would be under normal operating conditions. To mitigate this risk the investigators, should we receive an award, will immediately meet with Kenyan counterparts and potential financial institutions and value chains to develop a program through alternative funding sources to obtain the required loan pool.

4.2 Social and Environmental Impact Assessment (3/4 page)

With regard to social and technical impact assessment, the main risk is a mismatch between satellite-detected anomalies and actual drought impacts. A recent study of Vienna University of Technology and Doctors without Borders in the Central African Republic showed that false alarms are very risky with regard to the trustworthiness of satellite-derived information in general. The best way to limit the risk of such a mismatch is the careful retrospective analysis of satellite-derived information with regard to a broad knowledge base about past drought events. With respect to Kenya, this knowledge base is available from different national sources or existing social and economic assessments of international organizations, such as Doctors without Borders, Swiss Re East Africa, the Kenya Equity Bank or the UN World Food Programme.

The above mentioned risk of false alarms is not only related to an actual error in the used datasets, but also to the interpretation thereof. Our experience showed that this problem can be overcome by developing the visual representation of all information provided through SATISFy in collaboration with end users. In this regard it is also essential to maximize the understandability of all satellite data provided to users by combining maps for current conditions with time series that illustrate the evolution of a variable.

In addition, there are potential economic impacts related to the development of the RCC system and its implementation. There are always uncertainties related to the basis risk, which we aim to minimize by means of space-based information and regional assessments. However, these uncertainties are an intrinsic part of insurance systems. They require a careful investigation from the perspective of lenders and borrowers. In case of SATISFy the selected key players facilitate an in-depth assessment of uncertainties and a corresponding analysis of acceptable thresholds.

With regard to environmental impact assessment the findings created within SATISFy can affect both the use of water resources and agricultural practices, such as irrigation and the choice of (more drought-tolerant) seeds.

Section 6: Team Composition

6.1. List of All Team Members (1 page)

Team Role	Name	Title	Email	Phone Number	Organization
Team Lead	Liangzhi You	Senior Research Fellow	l.you@cgiar.org	+1-202-862-8168	IFPRI
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Team Member	Markus Enenkel	Post-Doctoral Fellow	markus.enenkel@geo.tuwien.ac.at	+43-58801-12210	Vienna University of Technology
Team Member	Carlo Azzarri	Research Fellow	c.azzarri@cgiar.org	+1-202-862-4608	IFPRI
Team Member	Jawoo Koo	Research Fellow	j.koo@cgiar.org	+1-202 862-8184	IFPRI
Team Member	Timothy Johnson	Research Analyst	timothy.johnson@cgiar.org	+1-202 627-4126	IFPRI
Team Member	Calum Turvey	Professor of Agricultural Finance	cgt6@cornell.edu	+1-607-255-5230	Cornell University
Team Member	Carme Baraldes	Project leader operational systems	carme.baraldes@barcelona.msf.org	+34 902 303 065	Doctors Without Borders (MSF) (Operational Cell Barcelona)

Team Member	Esther Muiruri	Manager	esther.muiruri@equitybank.co.ke	+254732112664	Equity Bank, Kenya
Team Member	David Mader-Soyka	Project Manager Agriculture	David_Maeder@swissre.com	+41432856310	SwissRe
Team Member	Hussein Omar Farah	Director General	farah@rcmrd.org	+254208560227	Regional Centre for Mapping of Resources for Development, Kenya

6.2. Summary of Team’s Strengths and Relevant Experience (1 page)

The International Food Policy Research Institute (IFPRI) in Washington, D.C. is one of 15 food and environmental research organizations supported by CGIAR (www.cgiar.org). IFPRI’s mission is to achieve sustainable food security and reduce poverty in developing countries through scientific research and research-related activities in the fields of agriculture, livestock, forestry, fisheries, policy, and natural resources management. The global food system has become increasingly vulnerable to shocks. IFPRI recognizes the need to build resilience and has included this as one of six strategic research areas. The 2020 conference on “Building Resilience for Food and Nutrition Security”, held in Addis Ababa in May 2014, helped advance the dialogue on resilience and identify research gaps, including defining and measuring resilience and taking a systems approach in policy and programming. Team members from IFPRI have demonstrated experience in the Horn of Africa and a thorough knowledge of the region’s farming systems, as well as the constraints faced by farmers and their crops. Technical expertise includes crop and economic modelling, spatial analysis, remote sensing, theoretical modelling, impact evaluation, monitoring and evaluating large programs in Africa, and financial innovation.

The Department of Geodesy and Geoinformation at the Vienna University of Technology conducts research and teaching in observing, modelling, and communicating spatial states and processes, specifically of geometrical and geophysical nature. This spans from the shape of the entire Earth and global processes to local surveying and modelling of natural and artificial objects, phenomena and processes, including aspects related to land and property ownership. Markus Enenkel is experienced in the interdisciplinary field between earth observation and humanitarian aid. He has worked with Doctors without Borders and developed satellite-based drought tools for different international or governmental organizations.

Doctors Without Borders (MSF) is an international, independent, medical humanitarian organization that delivers emergency aid to people affected by armed conflict, epidemics, natural disasters and exclusion from healthcare. MSF is a non-profit, self-governed organization. Today, MSF is a worldwide movement of 23 associations. Carme Baraldes is head of the MSF innovation unit at the operational center in Barcelona. She has demonstrated expertise in designing and implementing humanitarian field programs.

Equity bank, an on-the-ground implementing partner, is one of the largest banks in Kenya providing inclusive financial services and has a wide outreach including rural areas. The bank strives to transform agriculture from subsistence to commercially sustainable enterprises through inclusive financial intermediation in the agriculture value chains. This is done through establishment of strategic partnerships with stakeholders and developing innovative financial solutions that are capable of enhancing food security and increasing household incomes for farmers. Esther Muiruri is the general manager in marketing for the agribusiness unit at the bank, in which she founded, and has expertise in managing rural financial programs.

Swiss Re, another implementing partner from the private sector, is a global leader in agricultural reinsurance. Its global team of specialists partners with insurance companies and governments to help manage risks to the agricultural production system. They will add their vast global expertise of innovative agricultural re/insurance products to the development stage of the product. David Mäder-Soyka is Vice President in the agricultural reinsurance department and is in charge of managing the department's global portfolio of research & development activities. Projects range from mobile applications for clients to new modelling concepts for crop portfolios.

RCMRD is an inter-governmental organization operating in Eastern and Southern Africa Regions. Its mission is to promote sustainable development through generation, application and dissemination of Geo-Information and allied ICT services and products in the member States and beyond. RCMRD has vast experience in provision of GIS, remote sensing, GPS, statistical packages and relational database management systems and their applications in natural resources management and climate change impacts studies. Dr. Hussein Farah is a Kenyan National with expertise in all of the above.

Dr. Calum Turvey from Cornell University has expertise in agricultural finance. He has conducted extensive research using field surveys and experimental techniques all over the globe, including Africa (Ghana, Kenya) and has done foundational work in several aspect of agricultural insurance including weather insurance, revenue insurance and whole farm income insurance. He is also editor of Agricultural Finance.