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Recovery Lending to Build Resilience for Households, SMEs, and Communities

Designing Financial Disaster Risk Management Solutions to Support Recovery Lending via Microfinance Networks and Microfinance Investment Vehicles

Financial Disaster Risk Management (FDRM) solutions

FDRM solutions are a comprehensive package providing an optimized system for managing weather and seismic disaster events. FDRM solutions go beyond a simple risk transfer product by incorporating a set of tailored tools and products that blend risk analysis, risk retention and risk transfer to ensure a cost-efficient, highly effective end-to-end solution supporting ex-ante financing.

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Contributors

Many talented and busy individuals contributed their time and thoughtful review for the successful completion of this project and this document. Dr. Jerry Skees, Dr. Jason Hartell, Dan Bierenbaum, Richard Carpenter, Emily C. White, Dr. Michael Shaw, Bernard Van der Stichele and James Allen IV were principle authors. Charles Watson from Enki Holdings, LLC generated the climatology used in this project.

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Executive Summary

The innovation investigated by this project involves ex ante financing solutions for investments in low and middle-income countries that allow financial institutions to first ensure continuity of operations and service and, for many, to increase their lending after a disaster rather than restrict their lending which is the common behavior. If appropriate financing can be provided during these difficult times, households should be in a good position to recover their livelihood strategies. This dynamic contributes to more resilient households and communities. While there are clear social benefits tied to any program that allows for more lending post-disaster, there is increasing evidence that such “recovery loans” made during and after a disaster also represent good business for the financial institutions. Repayment rates seem to be as good or better than loans made under normal conditions and recovery lending helps the financial institution capture growth by serving new clients.

The approach taken by this project involves following the flow of capital from a global level down to the household. From a global level this analysis considers two key entry points for the financing of microfinance institutions (MFIs) operating in low and middle income countries: Microfinance Networks (MFNs) and Microfinance Investment Vehicles (MIV). MFNs tend to own the MFIs that they manage and provide both capital and debt to MFIs. MIVs are primarily involved in providing debt to MFIs; rarely taking any ownership of the MFIs they support. While MFIs offer financial services to households directly, MIVs, as the funders of those MFIs, are ‘one step removed’ from the end client. VisionFund International (VFI), the example MFN for this analysis, has been implementing recovery lending for some time and primarily owns its MFIs, while BlueOrchard Fund (BOF), the example MIV, primarily provides senior debt to MFIs. Given the difference in the business models of these type of institutions, VFI and BOF were selected for this analysis to represent two ends of the spectrum for financial disaster risk management (FDRM) to be applied at the global level.

Financial institutions can ensure their continuity of service and improve access by the poor and to financial resources post disaster and facilitate building resiliency for households and communities by following a three step process (Clarke and Dercon 2016):

1. developing coordinated plans for post-disaster action agreed in advance;
2. creating the ability for fast and evidence-based response; and
3. using FDRM solutions to fund the response.

Step 1: Developing coordinated plans

MFNs and MIVs are in a good position to incentivize their MFIs to perform risk analysis and the type of stress testing needed to understand what may happen to their business when there is an extreme event (i.e., drought, flood, tropical cyclone, earthquakes, etc.). This process will force better planning for how the MFI will cope when disaster strikes. MFNs and MIVs can also assist in building operational plans and/or ensuring that capacity exists to implement recovery lending post-disasters. A firm like Global Parametrics (see below for background) that can provide the science to assist in this planning process is important as disasters of consequence occur infrequently in most locations. Thus, MFIs who generally have a shorter history of operation may not have experience. Furthermore, the geography of the exposures changes over time necessitating a provider like Global Parametrics to adjust the exposure analysis to a ‘current view’ of how a particular disaster may impact a portfolio of loans, and is important for MFIs wishing to perform stress testing. Regulators in some countries are also requiring this type of analysis. As they do so, they are also requiring the financial institution to take actions to manage disasters.

Step 2: Creating fast evidence-based response

By using a consistent science-based approach, MFNs and MIVs can have the evidence needed to understand the consequences of various disasters and this evidence can be used in the response. The response should be proportional with the severity of the disaster (i.e., more financing is needed when the disaster is more severe). A firm, such as Global Parametrics, that is capable of using near real-time data to quickly identify the geography and severity of a disaster can provide the first evidence needed for the MFN or MIV to respond by either providing more liquidity to the MFI or, in the most extreme conditions, capital. This evidence can take many forms in terms of modeling to understand the event. Under this project, the focus is on statistical methods to bring the exposures (lending by geography) together with the measures of climatology to capture the frequency of the event. In insurance language, an event that occurs 1 in 10 years is referred as having a 10-year return. Events having a 50-year return are expected to have more dire consequences than, for example, events with a 10-year return.

Step 3: Financing the MFI based on the science

Ex-ante financing is accomplished via what is referred to as financial disaster risk management (FDRM) solutions. By using the evidence from the science, the MFN or MIV can take actions and support recovery lending programs. The FDRM system follows the rules of risk management whereby savings, access to credit, and then catastrophic risk transfer is used in sequence against event severity. For the more frequent events (e.g., 5-year return), using reserves (savings) to provide liquidity when needed is a prudent practice. Within a certain range of events, borrowing may be the best means to deploy emergency liquidity to an MFI. For more infrequent and extreme event, access to capital via a risk transfer mechanism to rebuild the balance sheet and, in the process, restoring the MFIs ability to borrow.

By having three sources of ex-ante financing on standby to provide assistance to their MFIs when there is a disaster, the MFN or MIV is also organizing a flexible FDRM system. This type of flexibility is important as it is difficult to map the full scope of the consequences of a disaster on the operations of the MFI. It is also difficult to know how much financing may be needed to effectively implement recovery lending. In the analysis that follows, for VisionFund International, the MFN example, an FDRM system that blends all three types of financing (reserves, credit, and risk transfer) is developed. As an alternative structure, for BlueOrchard, the MIV example, a model for acting as an emergency liquidity provider for MFIs through credit is considered. For both examples, the science and financial tools can be used to implement a program of recovery lending with the MFIs. There are clear incentives to implement such a program as it will allow them to continue supporting good clients (MFIs). This will build client loyalty and allow the MIV or MFN to grow their portfolios and gain market share by providing ex-ante lending options to their MFIs.

Global Parametrics

Global Parametrics (GP) is a newly founded socially oriented venture that is well-positioned to provide access to the full set of services needed by MFNs, MIVs, or directly to large MFIs to make much of what is developed within this report possible. GP will have the science, risk advisory services and, at some stage, the risk capital needed to implement the concepts presented within. GP will work with partners to provide the liquidity needed to fully implement the FDRM solutions. Of some importance, GP is supported by the development financial institutions with the first investment from the KfW supported Climate Insurance Fund. GP is meant to provide new solutions that will grow insurance services for the global market to better serve investments in low and middle income countries. Thus, success that follows ideas presented within will provide a significant public good for building markets and serving the poor and vulnerable in low and middle income countries in a fashion that also builds resiliency.

Introduction

This report summarizes the research and discovery supported using a grant from the Rockefeller Foundation under the Global Resiliency Platform. The best description for the contents of this report is that it presents –

A global approach to ex-ante financing systems supporting recovery lending post disaster

Currently many financial institutions (FIs) operating in low and middle income countries and their investors are making decisions and managing operations with limited knowledge of natural disaster risks exposures within their portfolios. When disasters occur, FIs experience a spike in portfolio-at-risk (PAR) and may have long term capital erosion. In response, lending dries up and the cost of borrowing increases as FIs and their investors tend to withdraw from disasters. This practice misses out on key opportunities to reinforce existing clients and grow new ones, and instead, pushes the biggest burden of disaster events down to the local borrowers and communities of FIs.

The ex-ante financing systems presented in this study are referred to as Financial Disaster Risk Management (FDRM) solutions. By following a three step process, financial institutions can improve their services to the poor and vulnerable post disaster and facilitate building resiliency for households and communities. The three step process involves:

Step 1: Developing coordinated plans for post-disaster action agreed in advance.
Step 2: Creating the ability for fast and evidence-based response.
Step 3: Using FDRM solutions to fund the response.

Financial Disaster Risk Management (FDRM) solution

FDRM solutions are a comprehensive package providing an optimized system for managing weather and seismic disaster events. FDRM solutions go beyond a simple risk transfer product by incorporating a set of tailored tools and products that blend risk analysis, risk retention and risk transfer to ensure a cost-efficient, highly effective end-to-end solution supporting ex-ante financing.

The term “risk transfer” is used to describe the objective of the contracts and insurance-like products envisaged within this report. The intent is that the parametric-based risk transfer product will have many of the features of an insurance contract. In particular, the payment received on the triggering of the index will enable part of the risk of an extreme weather event (with adverse consequences) to be transferred through the product. The legal nature of the contract that constitutes the parametric risk transfer product will depend in part on the legal and regulatory frameworks that apply to the parties. Although the parametric risk transfer product is intended to provide insurance-like benefits and insurance concepts have informed its design, the product is more likely to be sold as a derivative contract than as an insurance contract. These issues are discussed further in Section 11 of this report.

Financial institutions using FDRM solutions can gain key competitive advantages:

- ✓ More stable capital base and higher income from increased lending
- ✓ Improved lending capacity after disaster when credit is most needed to support borrowers reestablishing businesses and rebuilding livelihoods
- ✓ Better knowledge of risks for monitoring and long term strategic planning
- ✓ Increased confidence to operate in disaster prone regions facilitating further financial inclusion
- ✓ Improved customer loyalty, new opportunities for portfolio growth
- ✓ Improved confidence of the FI among commercial lenders that provide wholesale funds
- ✓ Increase attractiveness from donors and social investors

Global Parametrics

Of some importance, a new institution, Global Parametrics (GP), has been launched to implement many of the ideas presented in this report. GP has been supported by the UK's Department for International Development (DFID) and the German KfW's Climate Insurance Fund. GP is meant to provide new solutions that will grow risk transfer services for the entire global market to better serve investments in low and middle income countries. The three dimensions of FDRM solutions that GP will structure include:

1. SCIENCE AND RISK DATA

GP will use a proven Natural Hazard Platform having global coverage, with reach to any region on the planet. Perils include drought, extreme precipitation, and temperature, and cover for tropical cyclones and earthquake. Analysis of major risk events will include:

- ➢ historical risk assessment of weather events based on daily data back to 1979,
- ➢ historical risk assessment of tropical cyclones and earthquakes,
- ➢ near real-time (daily, weekly) feeds on ongoing events, and
- ➢ forecasts of tropical cyclones and droughts.

2. OPTIMIZATION

GP will advise clients on an optimal blend of instruments including reserves, credit and risk transfer to efficiently manage disaster risk exposures and **minimize the cost** of protection. Risk transfer products should only be relied on for more severe events, while credit and reserves are often more efficient means to finance response to more frequent and moderate disasters. GP will **design contingent credit products** using GP's science and can facilitate credit access for disaster response through third party sources.

3. RISK TRANSFER

As a first suite of products, GP will offer **parametric risk transfer contracts** based on the local disaster events at the province or state level in each country of interest. A single offering of risk transfer can aggregate the local risk to provide a single global contract at the portfolio level, reducing the overall cost to the client compared to multiple individual offerings. Parametric risk transfer products rely on indexed measures of event severity using GP's Natural Hazard Platform to determine the level of payment, facilitate quicker payments, and reduce transaction costs.

Theory of Change

This report begins with academic literature and practitioner experience to build a theory of change for how a strong local financial sector can both help households recover their livelihoods faster and help the community build back better post disaster. We argue that, among other institutions, microfinance adds a complementary dimension to more programmed relief efforts following disasters by utilizing the deep local knowledge of MFI's and empowering borrowers to take advantage of local conditions to restore their livelihoods. It is postulated that this dynamic will create more resiliency than some other interventions and, if used properly, will lead to less cost for the global community in the long run.

Relief funding modalities have historically taken little account of local financial markets–which can be dominated by microfinance–as a relief mechanism. Even in instances where credit funding schemes have been implemented following large disasters, they have often been too restrictive to be utilized by any but the strongest institutions while the more fragile MFI's are unable to take advantage of the funding made available. Policy makers, donors and MFI funding institutions should carefully consider options to strengthen MFI balance sheets following a disaster, taking account of the positive social impact that lending can have on livelihood recovery of the poor while being very cautious not to create moral hazards. To this end, the proposed FDRM solutions in this report pays on events that are outside the control of the local community (parametric triggers from estimates of local climate anomalies).

Structure of the Report

Section 2 brings the economic literature to bear on disasters, poverty and banking and lending in underdeveloped markets. This review provides the foundation for Section 3 which makes the case for recovery lending by emphasizing that the poor bear the brunt of disasters given current lending practices and that recovery lending is showing promise for both social purpose and as good business. This provides the backdrop to present the basic principles of FDRM solutions. Sections 5 through 7 follow the three-step process for developing FDRM solutions.

Section 5: Step 1 Developing coordinated plans

A critical underpinning of efforts to develop coordinated planning for natural disaster risk and an evidence based response system is a rapid risk assessment, including stress testing the financial institution with scenario analysis to consider the consequences of extreme natural disasters. A rapid risk assessment seeks to provide a clear characterization of important specific risks and how they affect both the financial institution as well as its clients. Just as the banking regulatory framework requires stress testing, those supporting financial institutions in low and middle income countries should also do so. Such analysis fits well with the planning needed.

Section 6: Step 2 Fast and evidence-based response

This section describes the science used to take Step 2 – the ability for fast and evidence-based response. In this report the science is focused only on weather events (i.e., drought, extreme rainfall events and extreme wind that accompanies tropical cyclones). The same processes can be used for seismic events. Enki Holdings, LLC used proprietary systems to create the historic climatology in a consistent fashion for low and middle income countries of interest for this study. The data are also available via an open source license through support of this grant (Annex I). To be clear, once financial institutions have these types of historic data, they can be used to enhance Step 1 (the planning process and portfolio stress testing for actions post-disaster) using knowledge of the frequency and severity of certain extreme events.

Section 7: Step 3 Using FDRM solutions to fund the response

Sections 7 provides detail of the FDRM solution and the prototype risk transfer products that can serve the purpose. By using science for fast and evidence-based responses that trigger the use of various ex-ante financing mechanisms including savings or reserves, borrowing, and insurance-like solutions or risk transfer products, the full plans are funded.

Section 7 provides the overview and details for the approach for protecting or strengthening the balance sheet of financial institutions given a disaster so as to enable recovery lending. Section 8 focuses on how this process can be implemented via microfinance networks (MFNs) like VisionFund. Section 9 provides analysis that may be used by microfinance investment vehicles (MIVs) like BlueOrchard Fund. Section 10 provides a view of the value of pooling risk transfer products into a single offering over several countries for different extreme events.

Section 11 covers the issues needed to make the FDRM solutions envisioned operational. Some good structure and planning will need to be in place to assure that there is fast action. In considering how this may be organized, the idea that capital infusion could be provided as subordinated debt is introduced. As will be reviewed, this can provide more flexibility. Some details with the regard to the legal and regulatory structure is also reviewed in this section.

Finally, Section 12 concludes by returning to the progress made via this grant with a focus on the potential for how the FDRM solutions fit squarely with the Rockefeller Foundations' programs to build resiliency with households and communities. A core conclusion is that FDRM solutions that are discussed within can support lending in disaster-prone geographies whereby financial institutions could offer more services, including recovery lending. As with any undertaking of this nature, there are challenges and additional work to be completed to make these ideas work as envisioned. It is acknowledged that getting funds into many of these countries quickly remains a challenge. Making certain that the FI has operational systems in place to implement recovery lending is also a challenge. Another challenge involves the knowledge base or the processes to help financial institutions develop a view to match their liquidity and capital needs to various catastrophic events. Finally, while the science used for this study show promise, more work will be needed to build the science for tropical cyclones, flooding and earthquakes.

Section 2: Disasters, Poverty, Lending in Underdeveloped Markets[1]

Droughts, earthquakes, flooding, tropical cyclones and other climate shocks disrupt the lives and livelihoods of the poor and vulnerable. In low and middle-income countries lacking the resources, infrastructure and social systems needed to help the poor and vulnerable recover these shocks are even more devastating. The obvious direct impacts can be horrific. This captures the attention of the international humanitarian community. But what are the indirect effects on these households? Sadly, for those living in the path of natural disasters, the consequences are dire as access to financial services will be constrained even with expectations of an extreme event. Certainly access will be far less once an event has devastated a community. Considering the dynamics of household wealth, it is easy to understand that those living on the margin are more likely to either be pushed into permanent poverty or trapped in poverty due to natural disasters (Barrett et al. 2008).

The poor and vulnerable use coping strategies that are costly in the short and long-term. These coping strategies involve working longer hours if possible, selling off assets at low values, taking children out of school and putting them to work, reducing nutrition intake, and many other short-term actions to survive; all of which have long-term negative implications for household welfare.

> *In a study of the asset dynamics of households having different levels of wealth prior to a drought in Ethiopia and a hurricane in Honduras, it was confirmed that that the poorest segments in both populations suffered the most and had the slowest path to recovery (Carter et al. 2007).*

The promise of microfinance providing financial services to the poor and vulnerable faces many challenges. As this sector has matured, certain challenges (e.g., exchange rate risk) have been addressed with innovations like the TCX and MFX.[2] The challenges surrounding natural disasters, however, have not been adequately addressed. Natural disasters represent a highly correlated risk whereby a large geography is affected by the same event. For microfinance institutions (MFIs) serving clients who are concentrated in areas prone to disasters, this can be a particular problem. One practice is to restrict lending to sectors or geographies that are more vulnerable. Another practice is for the MFI to hold extra capital as a precautionary buffer during difficult times. Both of these practices are suboptimal. MFIs may ultimately decide that they must grow and create a more diversified portfolio by providing services to more sectors and across a larger

[1] This section includes material previously organized by GlobalAgRisk on behalf of VisionFund for a DFID funded project.

[2] TCX and MFX are special purpose vehicles that provide derivatives to hedge the currency and interest rate mismatch that is created in cross-border investments between international investors and local borrowers in frontier and less liquid emerging markets. The goal is to promote long-term local currency financing, by contributing to a reduction in the market risks associated with currency mismatches.

geography. These solutions may indeed work for the MFI, but may not work for the poor and vulnerable.

Different behaviors are undertaken by the MFI once a disaster occurs. Disasters are likely to create problem loans. Various steps can be taken to restructure loans, draw down reserves, etc., but all of these actions represent extra costs and business interruption. Thus, widespread disasters can be expected to negatively impact the institution's balance sheet. The stressed balance sheet and the concerns about lending to the poor and vulnerable who have just experienced a shock from a natural disaster, means that the most common practice post-disaster is to slow or stop lending to the poor and vulnerable. Clearly this is the moment that clients of the MFI have the greatest needs. Stronger demand and limited supply drives up the cost of interest compounding the problem. Thus, disasters mean that the average cost of capital and the volatility of the cost are greater in low and middle-income countries which are the least able to cope with disasters. These countries also tend to have some of the most extreme events.

Natural Disaster Impact on Economies and the Poor

Vulnerability and poverty are economic concepts where the relationship between development and the degree of distributional inequality are important determinants of the observed impact of natural disasters. Poverty and inequality dynamically affect economic choices, such as the level of disaster risk mitigation effort both individually and collectively. For example, while poorer countries are unable or unwilling to spend scarce resources on mitigation investments, and may be subject to a variety of other institutional and market limitations, high inequality at any level of average development also correlates with less resources being devoted to mitigation (Cavallo and Noy 2010).

Stylized observations emerging from the empirical literature include that smaller and poorer states are more vulnerable to natural disaster impacts (Clay and Benson 2005; Kellenberg and Mobarak 2011; Cavallo and Noy 2010; Loayza et al. 2012), that they experience more disaster related deaths (Toya and Skidmore 2007), that larger disaster events have a proportionally greater impact on poor countries than wealthy countries (Noy 2009), including larger losses relative to their GDP (Wenzel and Wolf 2013). Furthermore, the poor are not homogenous, with gender an obvious but often underappreciated distinction. While women and girls are frequently more vulnerable and hence experience greater negative impact from natural disasters, women also have important, but unexploited, contributions to make to disaster risk mitigation (UNISDR 2009). These and other studies have included socioeconomic characteristics and indicators of development as part of their investigations, but more is needed for a fuller understanding of the channels and magnitudes through which natural disasters influence income distribution, poverty and recovery (Noy 2009).

Disaster resiliency and prospects for disaster recovery at both the micro and macro levels are dependent on the availability of emergency and reconstruction funding, where capacity further depends on the functioning and penetration of credit and insurance markets (Kellenberg and Mobarak 2011; Loayza et al. 2012). Not only are formal financial markets critical for ongoing development and poverty alleviation, they serve an important risk management and recovery function (Becchetti and Castriota 2011; Khandker 2007; Skoufias 2003). In particular, financial markets provide a means through which to efficiently allocate risk and help minimize economic losses through the timely finance of recovery and reconstruction efforts (Garmaise and Moskowitz 2009; Loayza et al. 2012; Yaron 1997). When these markets exist the human toll and economic effects of natural disaster are less pronounced.

The poor are generally more vulnerable when financial access and formal risk management are limited (Loayza et al. 2012). Self-insurance strategies of the poor are costly in terms of current income and opportunity cost. In addition, localized informal group risk sharing and consumption smoothing strategies employed by the working poor are designed for idiosyncratic risks that are overwhelmed by highly correlated natural disaster events where group income moves strongly together (Anderson 1976; Becchetti and Castriota 2011; Skoufias 2003). Losses in the immediate aftermath of disaster are compounded by the temporary failure of local markets and employment opportunities, which further exacerbates livelihood disruptions. When consumption-smoothing efforts force the sale of productive assets, poor households face a real threat of persistent poverty, trapped in a state of low productivity that inhibits future growth (Barnett et al. 2008; Carter et al. 2007; Dercon 2005; Wenzel and Wolf 2013). Poverty can be further transmitted into the future via curtailed childhood education and poor nutritional status when there are few sources of financing for disaster coping and recovery (Becchetti and Castriota 2011).

Improving access to financial services to help moderate the effect of natural disaster, improve resiliency and speed post event recovery is more pressing with the recognition that the return period for some catastrophic natural events appears to be shortening, and as populations of the poor and vulnerable increasingly concentrate in disaster prone areas.

Perspective on How Lending Works in Under-Developed Markets

The focus here is on lending financial institutions, and on microfinance in particular, and their role of credit provision to the real economy, and for the working poor in particular. While formal banking services can help improve the risk management capacities and disaster resiliency of the working poor, correlated natural disaster risks also pose special problems for the availability and performance of these services. That is, the disaster risk exposure of a lending institution's borrowers can greatly constrain financial market development and overall access to finance (Collier and Skees 2012; Garmaise and Moskowitz 2009; Skees and Barnet 1999; Skees et al. 2004). Here, we describe the underlying economic dynamics of MFI lending and show how lenders react when many of their clients are exposed and/or impacted by a natural disaster event. It is important to recognize that non-bank lending institutions in underdeveloped markets are not usually subject to prudential regulation. To the extent that such institutions are regulated, this will usually extend only to their business conduct. In the circumstances, those supporting the financial institutions with equity and liquidity (e.g., MFNs and MIVs) may become the de facto prudential regulators and may require certain practices like stress testing for natural disasters.

Lending and the Information Problem

Research supports concerns that lending involves a fundamental challenge that can be framed as an information problem – if the bank lends to this potential borrower, will she repay (Diamond 1984; Stein 2002; Stiglitz and Weiss 1981)? Banks need some method for selecting good investments and holding these borrowers accountable. Collateral is one form of accountability. Developed country credit markets have expanded in recent decades with commercial banks lending to small firms due to new forms of collateral (e.g., accounts receivable, inventory, etc., Berger and Udell 2006). Information technologies such as credit bureaus have also contributed to this expansion by increasing both information about borrowers and their accountability through linking repayment to future credit access (De Young et al. 2004; Petersen and Rajan 2002).

These information problems are perhaps greatest in markets serving the poor (Armendáriz and Morduch 2010; Behr et al. 2011), small and medium enterprises (SMEs, Agarwal and Hauswald 2010; Beck et al. 2008; De Young et al. 2004; Peterson and Rajan 2002) and agricultural producers (Binswanger and Rozensweig 1986; Boucher et al. 2008; Hoff and Stiglitz 1990). For these borrowers, production risks are high; few formal financial records are available; collateralizable assets are few; and in some cases, potential borrowers are remote. Consequently, these are some of the least developed credit markets. For example, about 50% of SMEs in developing countries cite access to financial services as an operational constraint, and 40% report not having any access at a formal financial institution (Stein et al. 2013). Stein et al. (2013) estimate that this developing country credit market gap is over US$ 2 trillion. Formal SMEs account for approximately 30% of total economic output in these countries (Ayyagari et al. 2007). Given the important role of SMEs in developing country economies, the benefit from approaches that reduce these credit constraints could be substantial.

To reach the poor, MFIs have developed alternative approaches to overcome information problems (e.g., see Armendáriz and Morduch 2010). For example, these lenders offer improving loan terms over time so borrowers repay based on the potential of larger loans or lower interest rates. Also, group lending relies on the group to select its members, taking advantage of their private information, and holds all members accountable for repayment.

In both developed and developing countries, the community bank model is perhaps the most pervasive lending approach to overcoming information problems in MSME and agricultural credit markets. With this strategy, lenders imbed themselves in a community. They select borrowers based on their expertise in the local economy and the reputation of community members, and they monitor these borrowers through frequent interaction (Agarwal and Hauswald 2010, Behr et al. 2011, Uchida et al. 2012). For example, agricultural lenders often hire agronomists and maintain small rural offices near their borrowers (Wenner et al. 2007).

This approach has expanded credit to households and firms that would have otherwise been excluded from formal markets, but it has two important consequences for managing disaster risks. First, it motivates geographic specialization (BCBS 2010, DeYoung et al. 2004), constraining the ability of these lenders to diversify portfolio concentrations of disaster risk. Second, it increases lender autonomy (Houston et al. 1997, Stein 2002). Lending to informationally opaque borrowers creates opaque lenders. In contrast to commercial banks that can provide lending rules based on credit scores and collateral quality, the lending rules for these MFIs rely on judgment and qualitative information. Consequently, MFIs often find attracting new equity investors difficult (Portes and Rey 2005). Moreover, the challenge of communicating this information from a subsidiary to a parent company decreases the likelihood that lenders using the community bank model, or who are part of a bank holding company, will be provided additional support in periods of crisis (Stein 2002).

Lender Financial Structure and its Implications

While banks perform a variety of functions and often have numerous investments and sources of revenue, consider a stylized situation where the sole business activity is retail lending to the working poor for business investment, working capital, and consumption smoothing, which is supported by retail and wholesale funding. This stylized model closely aligns with the functions of many MFIs. The bank earns revenue from the interest rate spread between its source of funds and the loans it makes to businesses and individuals.

Figure 2.1 represents the balance sheet of this bank (Hartell 2014). The left-hand side describes the assets held by the bank (the use of funds); the right-hand side describes how those funds are sourced. These two columns must always be equal in size.

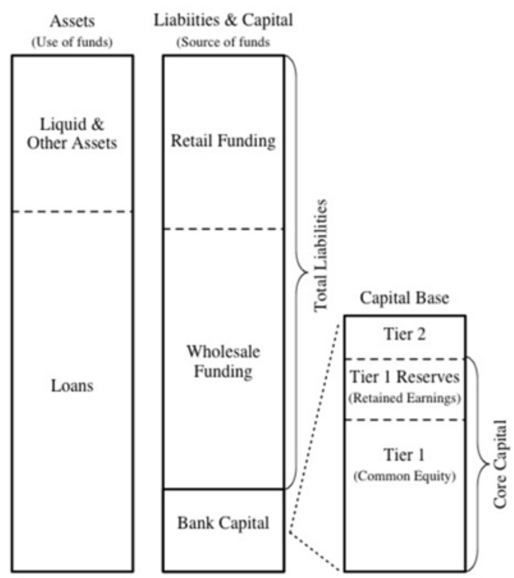


Figure 2.1 - Stylized balance sheet.

Lender Assets

Lender assets comprise cash and loans. Cash holdings are used for lending, address financial obligations, and manage liquidity risks, as discussed below. Loans are the main assets of the lender. A loan's value is a function of its current and expected performance. Credit risk refers to the risk that a lender's borrowers fail to repay their loans in part or in full on schedule. When a lender recognizes there is some likelihood of a loan not being fully repaid, it is considered impaired and the lender adjusts the value of the asset on its balance sheet (Krueger 2002).

Lender judgment also influences the adjusted value of an impaired loan. While standards differ across countries, frequently, they emphasize proactive management of credit risks and so loan quality depends on both the actual payments made by the borrower and the lender's assessment of the borrower's ongoing ability to repay (van Gruening and Bratanovic 2009). For example, impairment standards for regulated financial institutions in Peru state that a loan is "deficient" and its book value should be written down by 25% if it is in arrears for 60 to 120 days or if the borrower is in a weak financial situation and cash flow projections do not suggest improvements soon (SBS 2008). Additionally, standards provide lenders additional flexibility in that they typically allow poorly performing loans to be valued at higher levels if they are restructured (e.g., increasing loan maturity and reducing monthly payments, SBS 2008; van Gruening and Bratanovic 2009). Because lenders have an incentive to signal that their assets are of good quality, the discretion available to them challenges the external assessment of potential investors.

Lender Liabilities and Equity

Financial intermediation can be accomplished through several channels. One is through consolidation and transformation of many small deposits of short-term maturity into larger loans with a longer maturity (retail funding). Alternatively, institutional investors (second-tier banks or even donor organizations) provide funds for on-lending (wholesale funding). Deposits can reduce funding costs as retail customers typically accept lower interest rates than institutional investors, but deposit-taking institutions are more closely regulated to protect depositors. Moreover, deposits increase a lender's liquidity risk as these investors can often withdraw their funds on demand.

Equity (i.e. the interest of the owners in lending institution) is calculated by deducting total liabilities from total assets. Equity holders, whose interest represents their investment together with retained earnings (adjusted for accumulated losses), do not usually have any direct claim against the entity in respect of their interest unless the entity is being liquidated. Even then, equity holders usually have the lowest priority in any distribution of the assets on liquidation. In contrast to liability funding, which lenders can typically adjust as needed, equity therefore has a degree of permanence and can be used by a lender to build its operations and absorb losses. Equity is the most significant component, and often the only component, of a lender's capital.

Fixed claims (retail and wholesale funding) tend to be easier for banks to access than equity because the value of equity is determined by the value of its asset holdings, which is difficult to assess externally. With some exceptions discussed below, wholesale funding is primarily based on demonstrated cash flow – whether a lender's cash flow is likely to be consistent enough to service the fixed claim. Banks rely more heavily on liabilities than firms in other sectors (van Greuning and Bratanovic 2009). These forces increase the financial risks of banks. Banks need consistent returns to meet these liabilities. But also, large liabilities that are not offset by quality assets increase the risk of insolvency.

Diversification is the linchpin that allows this business model to work. On the assets side, lending to many borrowers reduces the consequences of nonpayment from a single borrower. On the liabilities side, holding deposits from many savers reduces the consequences of funding withdrawal from a single depositor.

Concentrations of risk in a lender's loan portfolio may remain after the lender has exhausted its ability to diversify. A lender's capacity to bear losses is largely based on its capital ratio, its level of equity relative to its risky investments (loans in this case). Thus, a lender with a capital ratio of 10% might face insolvency as non-performing loans approach 10%. All lenders must manage their capital ratio due to insolvency risk. Funding costs and equity share prices are also influenced by the capital ratio, motivating lenders to adhere to market norms. Almost universally, those regulated lenders that take deposits must comply with minimum capital requirements (e.g., that the capital ratio must remain above levels like 10%). Thus, whether regulated or unregulated, lenders tend to operate with an internal target capital ratio that provides some capacity to manage losses.

In underdeveloped markets where the need for credit is great, lenders are typically constrained not by profitable lending opportunities but by their capital. The capital base will largely determine the size of the loan portfolio. As an example, consider a bank that has US$1 million in capital and targets a capital ratio of 10%. This target capital ratio fixes a target value of outstanding loans at US$10 million (US$1 million/0.1). Without additional external capital, lenders grow through reinvesting profits.

Capital constraints limits wholesale funding opportunities

Capital constraints are apparent in development-oriented sector of "impact investing." Asset managers such as Blue Orchard specialize in investing in microfinance institutions, marketing their services as providing both a financial and social return. In periodic reports, the Consultative Group to Assist the Poor (2012), MicroRate (2011), Symbiotics (2013) and others identify access to equity as a capacity constraint for MFIs. These asset managers hold about 20% of their investments in equity and those in the largest and safest MFIs. They would like to provide additional wholesale funding, but the MFIs with which they work do not have enough capital to expand lending.

Summary

Lenders face an information problem in identifying to whom they should lend. Agriculture and MSME lending perhaps face the greatest informational constraints. Lenders serving these markets frequently specialize geographically, overcoming the information problem through developing local expertise and monitoring borrowers. Lending based on the judgment of loan officers creates a credit portfolio of assets that are difficult to evaluate externally and so limits access to additional equity funding. Instead, lenders rely on retail and wholesale funds that are structured as fixed claims. This model works as long as lenders can reduce risk concentrations via diversification.

Lenders and Natural Disasters

Lenders specializing geographically cannot fully diversify against local shocks such as natural disasters. In the developing world, disasters are first and foremost a credit risk. Loan losses reduce the returns and assets of the lender.

Disasters can also create two financing challenges. First, disasters create a need for liquidity. Second, disasters create a need for capital. Both challenges are a consequence of the information problem, which is exacerbated by disasters as the extent of lender losses will be externally unclear. If inadequately addressed, they can have lasting implications for the lender including insolvency (Berg and Schrader 2010, Collier and Skees 2012).

Disasters and Liquidity

Disasters increase demand for cash in the local economy to meet emergency consumption needs, offset business disruption losses for firms, and finance recovery and reconstruction. Frequently, depositors withdraw their funds as a result (Hoque 2008). Moreover, poor loan performance concurrently decreases lender revenues.

A liquidity crisis emerges if the lender cannot access enough cash to meet its current obligations (e.g., deposit withdrawals, debt servicing, operational expenses). At the extreme, cash shortages can motivate lenders to sell assets. Especially in developing countries, markets for unsecured loans are very thin and so can lead lenders to liquidate assets at fire-sale rates, taking substantial losses. Any investment (equity or liability) in the lender will tend to enter as cash and so can address liquidity shortages; however, short-term liabilities are typically well suited to address emergency liquidity needs as these events can be acute but short-lived.

Liquidity risk is typically managed through an appropriate mix of funding sources to ensure stability and by maintaining a buffer of liquid assets. First, lenders hold cash reserves. These cash holdings are costly. Second, some lenders have access to emergency liquidity funds through their governments or a private source. These emergency facilities are intended to provide a rapid injection of funds into otherwise healthy lenders facing an unusual stress event. They can be quite valuable for the lender and in turn the market is serves; however, whether to lend to a lender in crisis often remains at the discretion of the liquidity provider so these facilities are not a guaranteed solution to liquidity risk.

Disasters and Capital

For financial institutions focused on lending, capital is quite sensitive to loan losses. For a lender with a 10% capital ratio, losing 5% of its loans to a disaster translates into losing 50% of its equity. Without access to external capital, lenders may choose to deleverage, reduce investments in risky assets. This process effectively reduces the size of the lender to bring it in line with its smaller capital base. Secondary markets are thin in most developing countries for small business investment, working capital and consumption loans so the primary avenue to deleverage is through a reduction or temporary suspension of new loan origination (Collier et al. 2013; Collier and Skees 2012; Khandker 2007).

Using data from over 500 MFIs in 58 developing and emerging economies that report to MIX Market (2014), Collier (2015) finds that *disasters reduce lending following the event*. Median annual loan growth for these MFIs is 24%. On average disasters reduced loan growth by 11 percentage points in the current year and another 8 percentage points the following year. These effects are largely explained by capital constraints. Lenders with low capital ratios before a disaster lent substantially less afterward, but those with high capital ratios lent at the same rate following the event.

Unfortunately, deleveraging by distressed lenders comes at the precise moment when the affected community most needs robust or even expanding financial services to assist victims. Financial services have been shown to reduce the economic consequences of natural disasters (Zander 2009). These missed opportunities represent delayed recovery and more suffering for affected communities.

Lenders manage capital risks by operating with large capital reserves and rationing credit. Those lenders who have limited ability to diversify their portfolio or avoid areas at higher risk to correlated disaster events are forced to maintain higher precautionary capital buffers, holding capital well above regulatory minimums or market norms. For example, while regulated minimum capital requirements are typically 8-10%, the average capital ratio of lenders reporting to MIX Market (2014) is 38%.

The implications of this strategy are huge for communities with underdeveloped credit markets since higher capital buffers implies less lending for each dollar of equity to cushion against an infrequent but severe shock. Returning to the example of a lender with US$1 million in equity, a 10% target capital ratio as might be seen at a commercial bank would lead it to hold a portfolio of US$10 million. However, a capital ratio of 38% results in total loan allocations of only US$2.6 million.

Van den Heuvel (2006) goes further to show that lenders will reduce loan origination following a shock to its capital base even when bank capital erosion does not fall below regulated minimums, and that this effect can be persistent. Given the substantial operational challenge and cost of these undiversifiable shocks, it is perhaps unsurprising that lenders avoid vulnerable populations and communities despite the presence of profitable lending opportunities during non-disaster conditions (e.g., Boucher et al. 2008; Hoff and Stiglitz 1990).

Disasters and Credit Rationing

Natural disasters damage lenders and induce price and non-price rationing to preserve survival and profitability. Rationing behavior is not only a consequence of efforts to cope and deleverage following a disaster event that erodes the lender's capital, but also as a means to protect the institution from future events.

In isolated credit markets, the combination of effects is internalized and forces up interest rates (Ray 1998) or can be expressed as an increase in the minimum loan size in order to lower per unit administrative costs (Jonston and Morduch 2008). In some situations of slow onset disaster or where there are reliable indicators of an impending natural disaster, lenders may simply curtail additional lending until the crisis has passed to avoid predictable default problems. This reaction was found among some agricultural lenders in areas of Northern Peru at risk to El Niño induced rainfall and catastrophic flooding (Collier and Skees 2012; Skees et al. 2007).

Rationing can also be expressed through preferential lending in ways that minimize the information problem and default risk. For example, Berg and Schrader (2011) shows that relationship lending is an important rationing device when credit demand exceeds bank capacity following volcanic disasters in Ecuador. While overall lending declines, clients with known histories of good repayment are just as likely to be approved for a loan before and after the disaster disruption. Unknown clients are less likely to be approved for a loan after the disruption. In related work, Berg and Schrader (2010) also find that the same known clients were offered preferential interest rates following the disaster while new clients were charged higher rates. While the higher rates also resulted in higher default among new clients, the preferential treatment of known clients help maintain a monopolistic lending dynamic that would allow the lender to recover lower returns in the future.

Managing disaster risk as a bank holding company: A contrasting case

Bank holding companies (groups of banks that are typically organized with parent and subsidiary banks) also lend in areas experiencing disasters. These lenders operate "internal capital markets" by which they can reallocate capital and liquidity toward the greatest needs in the group. Hard information (credit scores, borrower financial records, collateral, etc.) greatly improves the functioning of internal capital markets. Soft information (lending that relies on lender judgment) can put the parent office in a difficult decision of differentiating between bad luck – losses due to a disaster that could not be avoided – and bad management – imprudent lending practices by the local office (Stein 2002).

Large banks have been shown to use internal capital markets inter-regionally (Campello 2002, Houston et al. 1997) and internationally (De Lis and Harrero 2010). Lenders with access to these internal markets behave differently. Independent banks target higher capital ratios and exercise additional caution after a shock to manage their scarce capital; however, bank subsidiaries with international parents hold small capital reserves and lend more after a shock based on their access to additional capital if needed (De Haas and Van Lelyveld 2010).

Similar bank lending channel impacts are documented by Mian and Khwaja (2006). They show that developing market lenders that face liquidity shocks frequently transfer these instabilities to their client when there are credit market imperfections affecting both lenders and clients. The effect of lender damage is a rationing of the amount of credit offered, with both new and existing clients having a lower probability of obtaining a loan even if the client's creditworthiness is unchanged. They show that larger firms, which are better known to other lenders, typically found alternative sources of funding, but smaller firms did not. Firms that could not find alternative funding in essence absorbed the liquidity shocks of their lenders and were significantly less profitable in the following periods. Even in well-developed capital markets, the impact of natural disasters can result in a decline in lender capacity and transmit rationing effects even to firms unaffected by the disaster event (Hosono et al. 2012).

Financing Recovery After Disasters

In a recent unpublished paper, "Financing Recovery After Disasters: Explaining Community Credit Market Responses to Severe Events", Benjamin Collier and Volodymyr Babich explore the effects of natural disasters on credit supply in low and middle income countries.[3] An important

[3] A previous version of the paper is available at http://opim.wharton.upenn.edu/risk/library/WP201402_CreditAccess+ClimateRisks.pdf

premise to this research is the assertion that in both developed and developing markets credit often provides a critical means for households and businesses to manage disaster losses. For example, earlier work by Collier found that following Superstorm Sandy in New York 40% of negatively impacted businesses increased their debt following the disaster. In fact, more of the firms impacted by Sandy borrowed to finance recovery than received insurance payments. As Collier and Babich explain, credit provides much needed cash in a crisis and can allow firms to replace lost assets, increasing their earnings opportunities after a severe event. Given the limited penetration of insurance markets in low and middle income economies, the potential role of credit in managing disaster losses is therefore particularly important.

Collier and Babich's analysis considers a panel of 929 financial institutions that lend to households and MSMEs in low and middle income countries. The dataset spans 78 countries and 18 years. This robust analysis finds that financial institutions in general reduce lending after natural disasters. The most severe disasters result in a reduction of annual loan portfolio growth by 30 percent on average. Based on the panel of data, a core driver of this behavior is capital constraints experienced by institutions effected by the disasters. Lenders have difficulty replacing equity lost due to systemic borrower repayment problems from the event. The study considers two groups of institutions, high capital (i.e. ample capital cushion) and low capital (i.e. more leanly capitalized), and finds that institutions with a low capital position pre-disaster reduce lending substantially more while high capital institutions tend to continue lending at the same rate post disaster. Low capital lenders are shown to reduce annual loan growth by 81 percent following large disasters. The analysis also compares the behavior of lenders across countries with relatively high and low insurance penetration. Collier and Babich find that in low insurance coverage countries credit reduction is accentuated with even high capital lenders reducing lending after disasters. Collier and Babich conclude that this outcome is likely due to a perceived deterioration in the creditworthiness of borrowers where households and MSMEs are less able to protect their assets with insurance.

Given the important role that credit can play for recovery, these results suggest a shortfall in the financial services market's ability to respond to communities' needs post disaster and an important opportunity for insurance markets. Collier and Babich conclude that finding ways for financial institutions to transfer natural disaster risk from their capital base through insurance or financial hedges could offer a useful means for lenders to increase access to credit for households and businesses after major disasters.

Section 3: Motivation and Experience with Recovery Lending

The previous section provides both the conceptual and empirical basis for a deeper understanding of the intersection of poverty, banking and natural disasters. In general, as financial institutions (FI) mature they implement common practices to manage disaster events. These practices include lending in more geographies, putting limits on lending to any single sector (e.g., agriculture) and even restricting lending to certain geographies or sectors (known as redlining). It is also interesting to know that the practices in place do seem to assure that the FI will get repaid.

This section begins by considering what happens to the poor who have loans when there is a disaster. This is followed by reviewing some of the academic literature for loans that are made when there is a disaster and an overview of some of the experience of VisionFund in their recovery lending program. The existing empirical literature examining MFI lending as a recovery mechanism for households and businesses is fairly limited. What does exist however provides a number of important insights and design considerations that broadly support the business opportunity and the social purpose that would be needed by financial institutions that are considering implementing a recovery lending program.

What Actions do Borrowers Take Post-Disaster?

Over two billion people in the developing world lived on less than US $1,200 a year in 2012, according to The World Bank (2016). The wealth position of the poor makes them more vulnerable to climate change, extreme weather events, and all forms of natural disasters. While the material above focuses on how financial institutions cope and manage natural disasters, it is also important to consider how borrowers make adjustments to pay off their loans. The literature on how the poor cope with risk can be helpful. This literature is largely anchored in understanding the dynamics of poverty and the destructive actions taken by the poor (e.g., increasing the hours of work, taking children out of school to earn income, reducing food consumption, selling off assets at reduce prices due to the wide spread disaster creating this behavior with the community, etc.).

Of some importance to the sustainability of microfinance are the systems used to reinforce paying off loans under all circumstances. Financial institutions lending to the poor generally believe that they will have limited problems in getting the poor to repay. There is limited evidence of financial institutions becoming insolvent when there are extreme weather or seismic events. Borrowers understand that if they do not pay off their loans, they will be denied future credit. The coping strategies of the poor undoubtedly partially explain how the poor pay off loans. The coping strategies take time. What strategies might the poor use if they must pay off their loans quickly? Do they turn to another source for credit?

A number of early studies have examined the use of various coping mechanisms, including various credit mechanisms employed by the poor and vulnerable during the 1998 catastrophic flood event in Bangladesh that affected approximately 68% of the country. Khandker (2007), using household-level panel data, found that robust and well capitalized microcredit facilitated borrowing as a key coping strategy of poor and vulnerable households following severe flooding in Bangladesh. Access to credit, such as through microfinance organizations, enabled households to maintain both consumption and asset holding. Shoji (2008) employed a micro panel dataset to examine coping strategies of agricultural-based households during covariate shocks when mutuality fails. Under moderately severe conditions, the poor use interest-free credit from friends and relatives and increase hours devoted to fishing to smooth consumption.

Under the most severe conditions both of those coping strategies are replaced with borrowing from moneylenders at high interest rates, suggesting that access to formal credit markets would be helpful for household coping and recovery. Zaman (1999) and Hoque (2008) focus on the role of household participation in the Bangladesh Rural Advancement Committee (BRAC), a large microfinance provider, in coping and recovery from economic crises, including natural disaster. Hoque's work showed that BRAC participants *borrowed more, used more of their own savings, and sold fewer assets compared to non-BRAC households*, but nearly half of the households of both groups only coping activity was to increase time spent at work. Zaman describes the multiple efforts BRAC took to help their clients during the flood, including the ability to borrow an additional 50% of their current loan amount with repayment extended by six months. The loans were intended for both immediate consumption needs as well as for livelihood recovery. He found that the credit program was used in conjunction with other coping mechanisms, including reduction in food consumption, personal savings, and borrowing from both relatives and moneylenders. None of the studies, however, attempted to formally measure the contribution of credit access or use to livelihood recovery following the flood event.

Save the Children commissioned a study of microfinance lending on long-term indicators of child welfare after the 2004 tsunami that struck Aceh, Indonesia (Stark et al. 2011). The evaluation was undertaken four years after the loan intervention and focused on the "Group-Guarantee Lending and Savings" (GGLS) program that specifically targeted women, where the rationale was that the extra income earned by women would be used for the family unit. The study intended to move beyond traditional financial indicators of microfinance lending performance and focus on client outcomes, which included lending effects on health, childcare, diet and education.

While the evaluation found that there were no significant differences between welfare indicators for women who received loans compared to those who did not, it did find that the average loan amount predicted whether clients were still engaged in their business. The authors' interpretation is that higher loan amounts may make businesses more sustainable over time. Average loan size was around 42 US$ but the variation in loan size across the sample was not reported. The study suffers from several biases but does raise the important points that outcome indicators for recovery programs should look beyond MFI loan performance only, should carefully consider the anticipated time path of intervention outcomes, and that loan size may importantly determine the degree to which lending is capable to aiding successful recovery.

Becchetti and Castriota (2011) made use of a quasi-natural experiment to investigate the role of MFI recapitalization and additional lending as an effective recovery tool after natural disaster. They conceptualize that non-price credit rationing could be avoided using bank recapitalization and can serve as a recovery tool to correlated disaster events, possibly at lower cost than other donor supported modalities. Credit, rather than cash, has the benefit of not affecting income in only that short term and, if the loan is repaid, perpetuates financial flows. MFI recapitalization, in their view "acts as a sort of expansionary monetary policy for the poor". The context is that of a Sri Lankan MFI (Agro Micro Finance) whose capital base was depleted following portfolio losses of ~24% in the aftermath of the 2004 Indian Ocean tsunami. Real income was reduced for both those clients directly impacted by the tsunami as well as for clients experiencing indirect market disruptions, though the reduction was less for the latter. Recapitalization enabled the MFI to avoid default and continue lending.

Welfare indicators examined were the percent change in income and worked hours after financing, which was available to both directly and indirectly impacted clients. Lending was represented as a loan-to-income ratio measured as the size of issued loans scaled by the clients' post-tsunami, pre-financing monthly income. Loan size, on average, was found to be equivalent to nearly nine months of income, but with some important differences related to relationship lending practices and social objectives. For example, clients suffering the most damage, having lower income, and with longer seniority received loans first and larger loans relative to their income.

Evaluation results found that the poorest were the most impacted by the event and also demonstrated the most significant recovery over time. The loan significantly affected worked hours and real income for directly impacted clients but only income for those indirectly impacted. After three years, directly impacted clients had not yet fully recovered to their pre-disaster purchasing level while those indirectly affected showed significant improvement. Nevertheless, the effect of lending was found to significantly affect clients' recovery and relatively more so for directly affected clients, contributing to convergence between those most and least impacted by the event. The study, however, did not compare these outcomes with other types of recovery interventions.

In the same Sri Lanka and tsunami disaster setting, Becchetti et al. (2012) study MFI lending and client default using a panel data set spanning the period 1995 to 2011, composed of bank records and interview data of 200 individuals and 767 loans. As preliminary to the analysis, they note that following an 18% default rate, lending peaked after the tsunami due to recapitalization that enabled it to respond to an increase in credit demand. About half of post-tsunami lending was issued to those directly impacted. An interesting condition emerged around average interest rates that prior to the tsunami fluctuated in response to market conditions, in particular the inflation rate. Donor recapitalization, however, was conditional on the offer of favorable interest rates to those who were directly impacted. While the overall average interest rate fell after recapitalization, interest charges to those who were not or only indirectly impacted rose by an average of 8% in order to cross subsidize the reductions of the former. This has important implications later for strategic default among clients.

Of loan size determinants, the authors found that those impacted by the tsunami received larger loans relative to those not impacted, and that loans were provided post-tsunami even if outstanding loans had not been fully repaid, consistent with the view that without further financial support recovery may not have been possible, including repayment of previous loans. The authors also found a positive relationship of social relationships with both financial access and loan size.

Determinants of loan default probability showed no relationship between impact status nor an index of intensity of damages—default rates between impacted and non-impacted clients were similar—an unexpected result since one would anticipate less default among those clients without tsunami damage. Interest rates were negatively associated with default as were larger loans. However, credit history in terms of repayment or default is not associated with higher default post-tsunami. This is an important observation for MFIs as it shows that support following a disaster-induced default does not imply anything about future repayment performance. While the MFI showed a preference for existing business expansion and recovery over new business start-up in terms of loan size, probability of default was the same.

The interaction of the interest rate differential combined with group lending liability may have contributed to the higher than expected default rate among non-impacted clients. They suggest that group contagion (domino effect of group members having to support default group-mates) or strategic default (rational response to the additional cost imposed to support the tsunami impacted clients) could be at play, although they are unable to distinguish the two with their data set. Note that donor interest-rate conditionality for recapitalization may be partially responsible for the interest rate differential, although Berg and Schrader (2010) document preferential interest rate setting that occurs independently of donor conditionality in a study of relationship lending practices during crises events. Zander (2009) also documents similar opportunistic behavior of non-impacted MFI clients following the 2006 Yogyakarta earthquake in Indonesia. Becchetti et al. (2012 point to contingent repayment systems currently adopted in Bangladesh (Dowla and Barua 2006) as being able to mitigate strategic default, but that credit access may still be impaired for non-impacted or new clients. Their recommendation is to adopt individual compulsory disaster insurance as a way to avoid uncertainty in timing, amounts, and conditionality of donor funds for recapitalization following future disasters.

Research into asset dynamics and poverty traps is currently attracting much attention in development economics and was recently the theme of workshop hosted by the NBER (Economics That Really Matters 2016). While research questions abound, many studies focus on three basic questions: 1) Which types of capital are available to the poor? 2) What role/potential does each type of capital play in regards to escaping the poverty trap? and 3) What positive external interventions can be implemented to help the poor escape the poverty trap in a sustainable and cost-efficient manner? Among the types of capital discussed at the NBER workshop were human capital, natural capital, and financial capital.

In particular, financial capital has been seen as a key pathway out of the poverty trap for the past decade. Financial exclusion forces the poor to rely on their own savings or informal borrowing to invest in education or entrepreneurial activities, contributing to income inequality and stunted economic growth. On the other hand, inclusive financial environments and policies give the poor access to savings accounts and microcredit through structural and technological innovations. In 2012, it was estimated that 8% of adults in developing economies took out a new loan from a formal financial institution in the previous year (Demirgüç-Kunt and Klapper 2012). While a recent review of the literature finds that impacts from microcredit varies across different settings (Buera et al. 2016), it is clear that microcredit loans started many entrepreneurs who would have been otherwise excluded from the financial system. Microcredit may not be a panacea for the poor, but by promoting economic independence and targeting aspiring middle-class entrepreneurs, it continues to play an important role in improving financial inclusion in the developing world.

Understanding the dynamics of poverty and the practices of the poor who may seek loans from another source to pay off an existing loan when there is a disaster provides some concern for the unintended consequences that may follow disasters. If the poor turn to more expensive sources (Khandker 2007 evidence of the poor using moneylenders to pay off loans after the Bangladesh flooding), the clients of FIs suffers the most. Do these dynamics of disasters and the incentives to pay off loans partially explain worrying trends associated with over-Indebtedness? There is a need to understand more about how the poor repay their loans post-disaster.

What should be well understood is that the current environment whereby lenders withdraw loans post-disaster is *harmful to the poor.* To be sure, the current systems of lending to smallholder households and those operating small and medium enterprises largely pushes the effects of natural disasters to the borrower. The unanswered question is to what extent can recovery lending play a role in mitigating this problem.

VisionFund International (VFI) Experience with Recovery Lending

For some years, VFI has exhibited the willingness to make loans even in the difficult times associated with natural disasters.[4] There is growing evidence that recovery lending works for social purpose as well as for business reasons. VFI is also getting inquiries from others MFNs about their recovery lending program. Thus, the prospects for significant growth in this important endeavor are promising.

VFI has been active in lending into disasters at least since 2011 when a severe drought in Ethiopia caused a great deal of hardship for clients who were reducing their food intake, selling important assets, taking children out of school but still paying their loans. World Vision contributed to a VFI response that had a positive impact on clients, but this response was well into the drought cycle and consequences had already begun to mount for clients. Following the drought, which affected both Ethiopia and Kenya, rural lending fell by over 30% in both countries. With a more efficiently designed FDRM system in place, VFI could have more confidence to increase lending to disaster prone regions and, in the event of a disaster, act quickly to recapitalize the affected MFI to ensure clients can rebuild and, importantly, that others can gain access to much needed support following a disaster.

VFI has three unique characteristics that drive both its need to innovate in this area and its suitability to progress this set of solutions for the industry. Firstly, VFI is predominately a rural organization with the strategic intent to further extend its rural footprint by providing greater financial inclusion for rural communities; it thereby has a significant and growing climate risk profile. Secondly, VFI owns and controls a global network and so can take a global view on the disaster risks inherent in its loan portfolio. Thirdly, VFI has been partnered with the Sponsors of Global Parametrics for more than three years and has organized a significant implementation plan for recovery lending.

[4] Annex A reproduces a document prepared by VFI for the SEEP conference in September 2016. The reader is also encouraged to visit VFI webpage to learn more about their programs for 'Disaster Resilient Financing" http://www.visionfund.org/2395/microfinance/disaster-resilient-microfinance/

Recent recovery lending programs have been implemented without the complete set of FDRM systems in place. Nonetheless, the experience has shown promise. VFI developed an active recovery lending program following the devastation of the 2013 typhoon Haiyan that brought important and broad reaching benefits provided to communities that were devastated by disaster. Within the organization a clear view developed that more could have been done at a faster pace had the ex-ante financing been organized with FDRM solutions. Consistent with the FDRM solutions discussed in this report, VFI used the newsletter produced by GlobalAgRisk that reported the strong El Niño that was building during mid-year 2015 to secure £2 million from DFID to implement recovery lending in Malawi and Zambia (drought impact of El Niño) and Kenya (flood impact of El Niño). This program used 'Science first' to organize ex-ante financing (access to liquidity). The early results of this lending have been excellent, reaching more than 12,000 families with loans that have supported replanting and adaptation in light of the harsh conditions. Loan repayment rates for recovery programs have met or exceeded the rest of VFI's loan books and the financial institutions have expanded their lending.

While the activity in East Africa is still being evaluated, more is known about the recovery lending that was implemented in the Philippines. VFI had five of its branch offices in the path of Haiyan and clients were severely impacted. VFI surveyed their affected client base and found that roughly one-third needed extensions on existing loans, and that another one-third were requesting new loans to replace lost income-generating assets in order to repay their existing loans (VisionFund International 2016). Rather than stop lending, VFI secured USD 2.1 million of outside funds to support the impaired MFI and continue lending in the disaster area to help families recover their destroyed livelihoods. In all, over 4,900 small businesses run by existing as well as new clients were provided with a recovery loans.

In a survey of over 3,000 recovery loan clients implemented 20 months later, 96% reported that the recovery loan had been helpful in restoring their livelihood, where of these over half reported being fully recovered or better. Over 90% reported an increased income and about 80% reported that they believed that recovery after the typhoon would have been more difficult without the loan. Finally, over 90% indicated that they would recommend a recovery loan under similar circumstances (Asian Development Bank and Vision Fund International 2016). These findings suggest that the recovery loan played a constructive role for the vast majority of participants and, in many cases, prevented default on existing loans. In addition, because of the emergency funds injection, the VFI affiliate was able to avoid insolvency and in fact quickly expand its client base in the affected communities. This expansion in particular enabled the MFI to support the additional operational costs associated with the recovery lending effort.

Section 4: FDRM Solutions to Support Recovery Lending

Problem Statement

> *Currently many financial institutions (FIs) operating in low and middle income countries and their investors are making decisions and managing operations with limited knowledge of natural disaster risks exposures within their portfolios. When disasters occur, FIs experience a spike in portfolio-at-risk (PAR) and may have long term capital erosion. In response, lending dries up and the cost of borrowing increases as FIs and their investors tend to withdraw from disasters. This practice misses out on key opportunities to reinforce existing clients and grow new ones, and instead, pushes the biggest burden of disaster events down to the local borrowers and communities of FIs.*

As presented in the previous section, some progress is underway to address this problem. The recovery lending initiatives described in Section 3 are meant to put FIs and their clients on a different recovery trajectory post-disaster.

The contribution of the initial VisionFund and GlobalAgRisk collaboration was to demonstrate that, in part, a global market-based mechanism using FDRM solutions, can provide the financing necessary to preserve the continuity of the FI and enable a recovery lending initiative. In addition, it provided opportunities for a set of FIs to systematically evaluate the impact of natural disasters on their operations and how the use of risk transfer products can change outcomes. The value proposition of organizing FDRM solutions involves concepts of opportunity cost of current practices relative to FI being in a strong position to continue or increase their lending post-disaster that opens additional business opportunity while also serving the poor and vulnerable. Longer term externality effects should be a lower cost of capital and less volatility in the cost of capital; both of these effects mean greater long-term economic development and lower rates of poverty.

Blending Funds, Liquidity and Index-based Risk Transfer

An effective FDRM strategy is one that can effectively cope with multiple layers of risk in a cost-efficient manner. Figure 4.1 outlines when each component of the FDRM innovation comes into play. For the less severe and more frequent events, an FI will be expected to use their internal capital reserves to cover any impacts, as these events should be anticipated on a regular basis. As the severity increases and frequency drops to around 1 in 5 years, reserved or contingent liquidity are well suited to cover FI recovery lending needs following a natural disaster. Reliable availability of liquidity allows for quick distribution of funds and is generally more cost effective than paying for a risk transfer product for these more frequently triggered weather events. For the most extreme and least frequent events of around 1 in 10 years and beyond, a risk transfer product can provide additional liquidity or capital needs up to the amount of the sum insured. In this way, the strategy is designed to tap into additional sources of liquidity as event severity increases, with the aim of ensuring that there are always sufficient resources to provide recovery lending following a natural disaster.

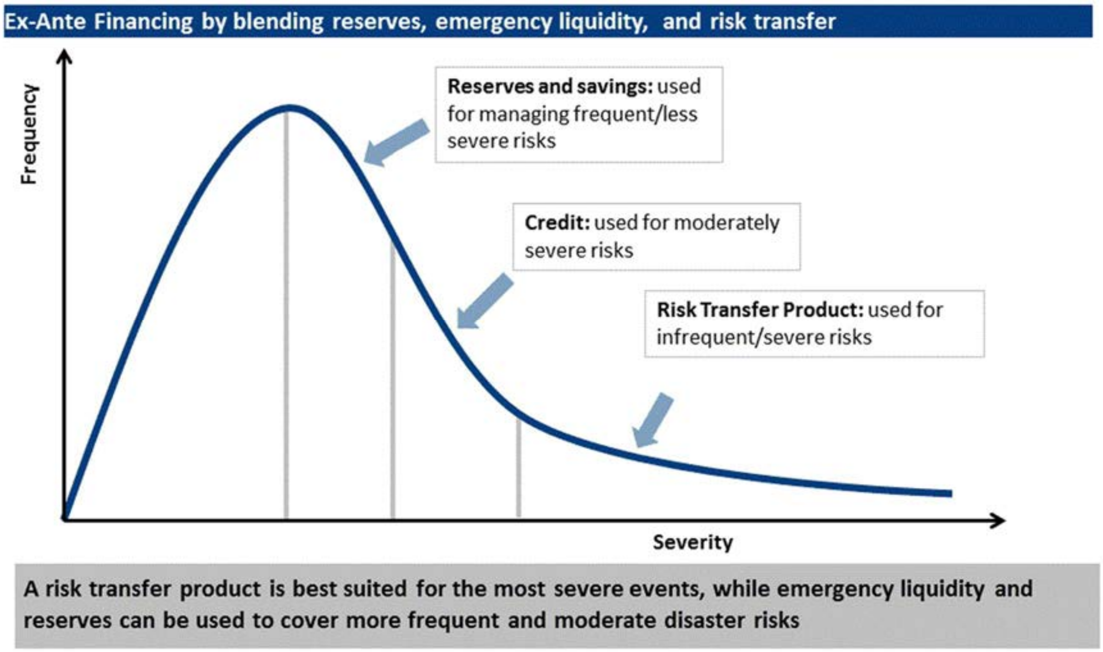


Figure 4.1 - Risk layering within a FDRM system.

Parametric Risk Transfer Products

The risk transfer product referenced as the third layer of ex-ante finance above is designed as an index-based, or parametric, insurance-like instrument. Historically, indemnity insurance has been the standard model for risk transfer products to businesses for property losses, damage to agricultural assets, and business interruption. Indemnity insurance products base payments on a direct assessment of the estimated losses of those insured. While such a process has clear logic for addressing claims that result from losses, it often requires extensive work by an assessor to determine payments, which can be costly and time consuming. In addition, indemnity products are more prone to information asymmetries, which create problems of moral hazard and adverse selection. Indemnity products require more data, strong legal and regulatory systems, and stronger institutional arrangements. Parametric FDRM, on the other hand, is able to mitigate many of these constraints. In particular, the ex-ante financing approach is to avoid problems associated with raising funds after the disaster has occurred, mobilize funds in proportion to the need, facilitate advanced disaster planning, and to introduce discipline in recovery lending. Table 4.1 summarizes the benefits of parametric structures over traditional indemnity products.

Table 4.1 Benefits of parametric risk transfer over traditional indemnity insurance.

Benefit	Description
Quicker Payments	More timely payments have the potential to add significant value to policyholders who are provided with those funds during difficult conditions. Parametric products provide payment based on a predetermined measure of the disaster event and so can be paid more quickly than indemnity insurance, which requires a loss assessment sometime after the event. Parametric risk transfer products using forecasts even have the potential to pay before an event, giving policyholders the opportunity to prepare for an event and reduce losses, as does the aforementioned El Niño insurance designed by GlobalAgRisk.
Broader Scope	Different entities are affected by the same event and there is potential for any vulnerable party to use the same risk transfer product structure. Indemnity insurance such as agricultural insurance only serves a specific set of those who are vulnerable. For example, agricultural insurance markets protect producers from yield losses but do not tend to be available for agricultural processors or wholesalers whose revenues are also adversely affected by low yields.
Greater Flexibility	Disasters create a variety of adverse consequences for those affected such as revenue losses, increased expenses, and asset losses. With parametric risk transfer products, the level of coverage is chosen by the policyholder, and the payout can be used for any purpose the policyholder chooses. Indemnity insurance such as property insurance traditionally will only protect against asset losses.
Lower Transaction Costs	By using a transparent third-party metric to trigger payments, parametric risk transfer products avoid the costs of verifying actual losses and are much less prone to problems of moral hazard and adverse selection that can dramatically increase the cost of indemnity insurance for agriculture or business interruption.
Better Form of Risk Protection for Business Interruption	Firms can purchase risk transfer products to protect against business interruption and extra costs that may be tied to an extreme catastrophe events. Traditional business interruption insurance is prone to legal disputes and prolonged court cases to resolve different assessments in evaluating loss. No disputes should emerge from FDRM. The event occurs and the conditions of the contract specify the payment based on a third party metric.

A FDRM Structure for Recovery Lending

Based on the principles of risk layering, a comprehensive FDRM strategy calls for ex-ante financing that includes both dedicated liquidity reserves for disaster response and parametric-based risk transfer in order to support recovery lending in the event of an extreme natural disaster. The design permits recovery lending to community members affected by natural disaster with the speed and confidence that will support the rebuilding of livelihoods in the most efficient way possible. The FDRM system is a proactive strategy that MFIs can adopt to prepare for rapid disaster response and support their clients when they need it most, without the uncertainty that external sources of funding will arrive.

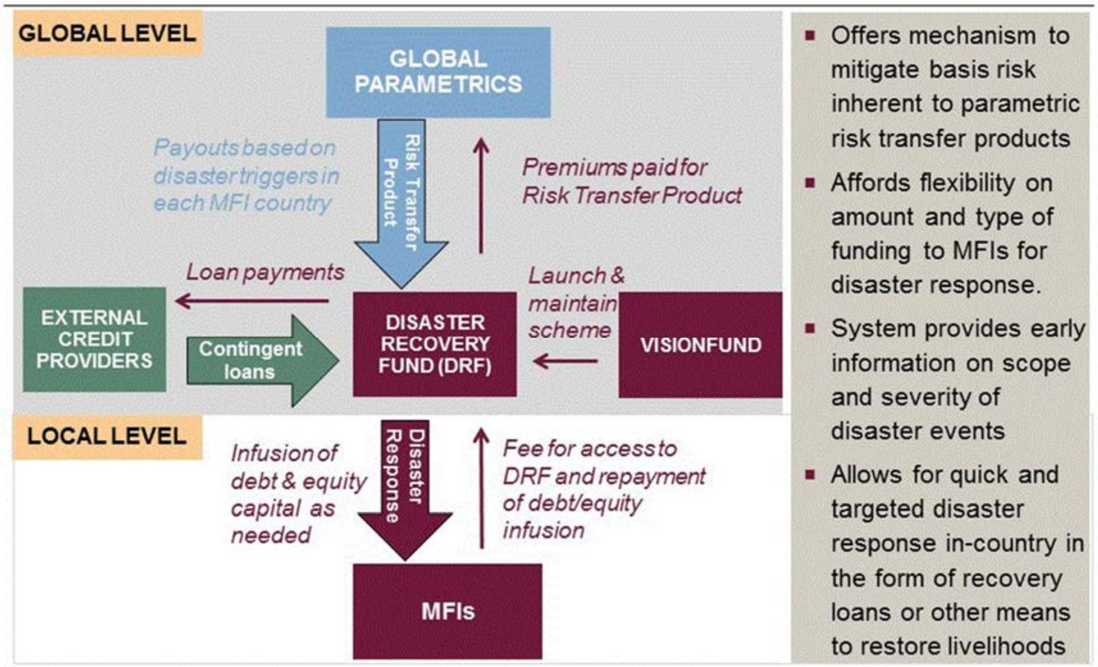


Figure 4.2 - FDRM system structure.

The structure of the FDRM system involves three formalized relationships that provide different types of contingent financing. Referencing figure 4.2, sitting in the middle is a dedicated liquidity reserve, here called a disaster recovery fund (DRF). This fund is owned or managed by the microfinance investor or network owner, and is used as the means to pool resources within the network. The DRF provides liquidity and/or capital funding to the individual financial institution on the basis of contract that is itself index-based and using the same science throughout the system. In exchange, the subscribing financial institution pays an annual access fee on the amounts of funds that could flow from the DFR. The DFR in turn enters into a contract with a risk carrier such as Global Parametrics for the parametric FDRM risk transfer for protection against the most extreme events. For additional liquidity needs, the DFR can enter into a contingent credit contract with a third party credit provider.

There are a number of entities that could provide external contingent credit facilities of the type required by the FDRM system model. In this context, contingent credit products involve fixing the terms and mechanism of lending before an event occurs. For the type of contracts that may exist between the DRF and the external contingent credit provider, a trigger drawdown that is structured similar to the risk transfer product is envisioned.

Using the same science for both the external call-down credit product and the risk transfer product is important for the DFR ensuring that it has sufficient funds to meet the contractual obligation it will have to its subscribing financial institutions.

However, the relationship between the financial institution and the DFR for access to contingent credit can be more flexible and extend beyond the index-based outcomes as indicated within the contract. The information around which flexibility is based is that which flows up from the financial institution with regard to realized needs, which can fluctuate around that indicated by the science. In this way, adjustments can be made up or down in the availability of funds and provides some ability to manage basis risk within the system.

Some of key motivations for this approach include:

- Immediately following a disaster, MFIs can help their clients in a number of effective ways including: repayment holidays, loan forgiveness and access to compulsory savings. More broadly they can also help disburse cash aid from humanitarian programs if needed.
- MFIs have a potentially bigger role in the recovery and reconstruction phases after a disaster taking advantage of their local knowledge and resources. They can provide recovery loans to support individuals in rebuilding their livelihoods and possibly homes, which offers a cost efficient way of supporting local economic recovery.
- Recovery loans can be positioned to be complementary to other tools in the disaster response toolbox. Getting a recovery loan should complement the recovery of certain beneficiaries receiving targeted humanitarian aid, livelihood support, etc. when appropriate to aid an earlier and fuller restoration of their livelihoods than might otherwise be possible.
- Recovery loans are not suitable for the highly indebted or those without viable cash generating livelihood options; but rather for the economically active poor, including (but not limited to) those not normally targeted for humanitarian aid. The support to this group should have a disproportionate effect on the community’s economic recovery.
- Bad debt provisions following disasters erode the capital base of MFIs and leaves them lacking solvency and liquidity, often making them unable to respond to post-disaster client needs. Under the proposed risk transfer product backed funding model they would receive sufficient capital and liquidity injections to address this deficiency and play their proper and full part in recovery described above.
- A “before the event” funding model is proposed using a risk transfer product that offers a sustainable and affordable way to build resilience against disasters of MFIs, and the clients and communities they serve.

The ability to transfer risk should allow microfinance networks to expand their coverage in at-risk (particularly rural) areas, improving financial inclusion and stimulating growth.

Section 5: Step 1 Developing Coordinated Plans

A critical underpinning of efforts to develop coordinated planning for natural disaster risk and an evidence based response system is a rapid risk assessment, including stress test evidence. A rapid risk assessment seeks to provide a clear characterization of important specific risks and how they affect both the MFI as well as its clients. This essential first level understanding of risk in the local and regional context where the MFI operates and where its clients pursue their livelihoods then interacts with the independent science-based weather modeling approach employed by GP to overlay an analysis of frequency and severity of historical events. These components provide the means to perform a variety of stress testing exercises to assess how the MFI is anticipated to perform today in the face of different natural disaster risks, using past events as a beginning reference. Keeping in mind that when the financial institution is formally regulated performing stress testing for the vulnerability when there is a natural disaster may be required by the regulator, it is logical to consider that the MFNs or MIVs supporting financial institutions may become the de factor 'regulator' that requires the stress testing. These processes inform MFI disaster contingency planning not only in terms of traditional means such as provisioning requirements, but in the design of disaster recovery lending and associated actions meant to assist clients recover their livelihoods while also preserving the MFI as a viable and responsive financial entity.

Basics of Rapid Risk Assessment

One of the first steps that a financial institution will need to undertake is the development of a risk event calendar that chronologically enumerates historical disaster events within its current and future operating area. It is important to be as specific as possible in developing the risk calendar since it will be used to provide the basis for assessing theoretical future impacts on the current portfolio, and contribute to the design and evaluation of the eventual FDRM response system. In addition, the event calendar provides a place where specific coping and response actions to the disaster can be described both for the MFI if it experienced direct impact as well as of individuals who experienced livelihood disruption. Not all past disaster events will have had a material impact on an MFI due to a variety of reasons including the disaster being outside its portfolio scope (i.e., clients, products) or due to the maturity of the institution itself. However, the lack of portfolio impact should not necessarily be construed as an indication that its clients have not experienced difficulties, perhaps being masked by degenerative coping activities on the part of clients in order to meet loan terms in order to preserve the lending relationship in the future.

The risk calendar will serve as a lasting record and reference as the MFI and network participants continually work to improve risk management systems. The calendar is developed through an extensive review of secondary literature and discussion with local professionals who can provide important context for both the events and the response. The effort will involve delving into several different classification systems.

- Classification by Risk Type

The risk event calendar will focus specifically on the correlated types of hydrometeorological and geophysical risks that give rise to widespread livelihood failure and lending portfolio stress.

Catastrophic risks are the focus precisely because it is especially difficult for individual households and financial institutions to manage this type of risk. For this current work, the focus is on widespread drought risk affecting farmers directly and consumers indirectly through food price increases and potential regional shortages, excessive precipitation that results in local inundation, and extreme wind that results from tropical cyclones. Regardless of current work, for completeness the risk event calendar should include all relevant severe events including overland flood, extensive landside, storm surge, and earthquake and tsunami effects.

- Classification by Regional and Timing Effects

The same type of risk can affect regions differently and therefore the risk must be understood in the local context. An understanding of the event's development across geographic space will be important for assessing the performance of the underlying risk transfer mechanism. Risk events can also have a differential impact depending on timing, and where the timing itself can define the event as being damaging. A good example of where timing is important is with seasonal flooding throughout particular river systems and its interaction with agriculture. Seasonal river system flooding is largely beneficial, flushing wastes and replenishing fertility. However, unanticipated earlier than usual flooding may disrupt harvest activities for crops such as rice or fish farming, resulting in significant direct and quality loss. In a similar fashion, drought can be experienced through a number of different processes and durations. In brief, the risk calendar assessment should attempt to capture the most important nuances of how a disaster event manifests itself over time and geography as is feasible.

- Classification by Exposure (Clients and Portfolio)

Just as the same type of risk may affect different regions differently, so too a risk may affect different segments of an MFI's client base and therefore portfolio in the same region differently. An MFI typically has multiple client types and specialized loan products tailored to specific financing needs that in turn represent varying degrees of vulnerability. For instance, more commercial orientated farmers who produce crops intended for export may experience different consequences than more subsistence farmers who consume much of their own crop. A catastrophic event may destroy roads typically used to transport the commodities of commercial farmers as well as the supply of goods of non-agricultural businesses; however, these infrastructure losses may affect subsistence farmers less severely. Conversely, yield losses may more severely affect subsistence farmers who tend to have less cash and more limited access to credit. Each of the identified risk event scenarios will have different ramifications for the MFI's clients and therefore portfolio performance. Assessing which livelihood/business groups and which lending products are most vulnerable to different risks will significantly aid in developing coordinated disaster response plans and financing.

Rapid risk assessment involves a commitment of resources to perform properly and is often underprovided in the development of financial risk management systems. However, it is an important resource and record that provides the necessary detailed view of important risk events, their regional effects and timing characteristics, and the exposure of clients and the MFI's portfolio. This knowledge becomes and important complement to the science of natural disaster risk management, specifically the use of modeled weather data to generate event frequency and severity mappings, and in the design of FDRM index risk transfer mechanism.

Stress Testing

Banking regulators for larger banks require financial institutions to conduct stress testing as a means to assure that the bank is properly prepared to manage certain risks. Stress testing involves scenario analysis. In cases where the financial institution is not regulated or when the institutions are regulated but their capital providers have more stringent requirements, the MFNs and MIVs may become the de facto regulator. Thus, the MFNs and MIVs can provide guidance to their networks for how to perform stress testing for extreme disasters.

The economic literature and the practical experience in working with MFIs in low and middle income countries bring some potential consequences into focus. Most financial institutions have organized their lending portfolio in a fashion whereby they believe that they can manage the level of non-performing loans and avert a crisis. This is generally done by expanding services to other geographies so that the same disaster does not affect the entire book of business, by placing limits for lending to any single sector (e.g., agriculture), and by restricting lending (redlining) to certain sectors or geographies deemed to be too risky. The latter practice conflicts with the goal of expanding financial inclusion. In summary, in the absence of risk management planning that includes ex ante financial solutions including risk transfer, a number of stylized MFI responses to natural disaster emerge:

- Highly leveraged and highly exposed financial institutions lending in exposed geographies will experience some stress when there are natural disasters.
- The effects on MFIs are generally a form of business interruption and extra costs that can also create balance sheet problems
- High capital reserves as a hedge against portfolio erosion due to natural disaster risk slow financial inclusion, while the risk premium increases the cost of credit.
- Impaired MFIs, those suffering arrears, liquidity shortfalls and default during and following a natural disaster, curtail or even suspend lending in order to bring their capital-asset ratios back into compliance. Hence, the financial capacity of the MFI to lend often falls just as credit demand for livelihood recovery efforts increase.
- MFI current performance indicators rapidly deteriorate, which make it difficult to attract funds needed to span the liquidity gap (even from dedicated emergency liquidity funds), may result in the suspension of planned pipeline wholesale funding, and may result in an early call on wholesale debt. All these threaten the survival of the MFI.
- In anticipation of these problems, many MFIs will place portfolio limits on certain sectors (i.e., agriculture) or certain areas that are deemed too risky. So even before there is a disaster event, financial inclusion and ultimately economic growth has been constrained.

Stress Testing Practice

The materials developed during a rapid risk assessment can be supplemented with disaster event maps or probabilistic hazard maps to provide a view of the frequency and severity of possible perils across a geography. These two elements provide the ingredients needed to begin conducting a stress test analysis with key informed members of the MFI management. Here, we consider two interactive processes under the heading of stress testing:

- Informal analysis where the magnitude and extent of past severe events are placed in context against an MFI's portfolio exposure in order to begin understanding the impact today of known historical events. This process helps to focus management's thinking about (1) the consequences of a disaster on its profile of loans, and (2) the actions it might take to adjust during a disaster in order to maintain minimums on certain performance metrics in the balance sheet. Estimating consequences for the portfolio across a number of known events contributes to developing a set of 'response functions' that can be used in further model-based analysis. The consideration of what actions to take under different historical disaster events is the first step in developing an operational menu of contingent actions to be taken by the institution depending on how a disaster event is manifest--that is, its realized or anticipated severity and extent. Furthermore, it helps to draw greater attention to the financial initial conditions of the MFI for items such as its current level and composition of capital, what performance metrics are most important in trying to preserve during a disaster event, the anticipated response from regulators and creditors given movements in performance metrics.
- Stress testing for financial institutions is normally understood in formal terms, where the institution, either out of self-preservation or regulatory obligation, seeks to estimate how its lending portfolio will perform during a period of natural disaster induced stress (or other financial disruption). Most applications focus on the interaction of credit and liquidity risk on the impacts of available capital or other metrics that are subject to regulatory minimums. Stress testing should be a feature of ordinary risk management practice even without the possible addition of an FDRM system and recovery lending as a planned activity following natural disaster. Stress testing is performed in a modelled environment of the MFI's business that incorporates the internal dynamics between the balance sheet, income statement, and assumptions on growth projections. Various disaster scenarios can be imposed in this environment, taking advantage of the 'response functions' developed in the previous exercises to simulate initial impact. The model then carries the impact forward to provide a view of how the disruption perpetuates, and dissipates, over time. These scenarios can include both the current structure of the MFI's operation as well as the inclusion of disaster response recovery lending and backstopping FDRM liquidity and risk transfer. Sophisticated stress testing techniques move beyond a single or small set of deterministic examples to simulate a large number of possible outcomes based on probability distributions of severe events and incorporating the correlation of various input parameters. Spatial dependency of risk events across geography, for example, can be incorporated. The advantage of this method is that it generates probabilistic results that communicate the likelihood of certain outcomes as well as robust sensitivity analysis useful for identifying the most limiting or influential model elements.

Again, risk assessment and stress testing even at rudimentary levels should be a component of any MFI's risk management planning for natural disaster. Where there is interest in creating a more resilient enterprise capable of mounting a recovery lending program or other actions for client livelihood recovery, these types of analysis become more crucial for understanding the dynamics of natural disaster impact on clients, the institution, and for understanding how the FDRM system contributes and enables differing outcomes.

Coordinated Plans for Disaster Resilient Finance

The risk assessment and stress testing exercise with the view of how FDRM systems can alter the financial consequences of natural disaster are ideal prerequisites for an MFI who wishes to implement some form of disaster resilient strategy. Such a strategy possibly includes elements of recovery lending, meant to assist clients recover their livelihoods while also preserving the MFI as a viable and responsive financial entity. The range of options that a microfinance organization ordinarily has at its discretionary disposal to respond to a natural disaster event is fairly limited, and in most cases there is no established protocol that enables a modified response at the client level.

Developing specific actions, product structures or procedures for implementation by the local MFI is beyond the scope, and competence, of this project. However, the use of FDRM solutions is meant to expand their choice set of feasible actions that can be taken during a natural disaster.

The development of a coordinated disaster response plan will most frequently be a tailored set of activities and lending product adjustments that are specific to the culture and knowledge of the local MFI. However, there are a number of principles that can be delineated when considering how to structure such plans. The following principles are excerpted from a recent VisionFund report "Blueprint for Disaster Resilient Microfinance: VFI Tanzania" which is incorporated as Annex B of this report. It provides for an initial view of the level of detail and local expertise that must be considered when organizing a disaster response and provides an initial blueprint of options and sequences that can be adopted.

The design principles identified include:

- Client led — Empower the client to make choices and take action.
- Do no harm — Be diligent in preventing client unsustainable indebtedness and default.
- Preservation — Maintain the client relationship through the disaster event.
- Sufficiency — Help the client cushion enough of the impact to enable them to recover a sensible livelihood after the disaster.
- Sustainability — Do not jeopardize the MFI's ability to provide continuity of service.

Each financial institution, however, will have its own view of what specific elements constitute financial resilience, and have differing abilities in offering services during difficult times.

Section 6: Step 2 Science First---Modeled Weather Event Data

The development of efficient and sustainable index-based risk transfer mechanisms requires the actuarially sound quantification of risk. Natural disaster risk transfer, specifically, calls for a scientific approach to evaluate the risk of occurrence (i.e. frequency) of natural phenomena such as temperature and rainfall extremes. Scientific advances over the past several decades have both improved scientists' ability to understand and model natural phenomena, as well as the availability and quality of historical weather data.

The quantitative basis of weather-related risk assessment relies on historical data describing past weather dynamics and extremes. Even though great strides have been made by atmospheric scientists, meteorologists, hydrologists and other scientists in understanding the drivers of weather dynamics, the assessment of the *frequency* of significant weather events still relies greatly on historical weather data. The availability of long and reliable historical data records has, until recently, limited our ability to evaluate weather risk. In fact, the availability of long and reliable observational weather records is biased in favor of the most economically-developed nations, which have benefitted from a long tradition of weather record-keeping linked to commerce, public support of science, as well as from advances in satellite technology and coverage.

Modeled Weather Data: A Step Change in Risk Transfer

The application of science-based risk modeling to mainstream insurance and reinsurance markets is relatively recent. In fact, it is only in the mid 1990's that commercial risk-modeling tools became available to insurers and reinsurers to help them evaluate and quantify their exposure to natural hazard risk. The evolution of such tools has enabled the insurance industry to better manage increasing industry-wide exposures to so-called catastrophe risk, especially in the property insurance markets.

Today, commercial catastrophe risk modeling platforms are in widespread use in the reinsurance markets of North America, Europe and parts of Asia (Japan). However, existing commercial catastrophe risk platform are limited to the evaluation of only a few natural hazard risks. If we consider wind-related hazards (e.g. tropical cyclones, tornadoes, winter-storms), commercial catastrophe risk modeling firms have typically developed their risk models on the basis of distinct regional hazard models. For example, developing a distinct model for North Atlantic hurricane risk and a distinct model for severe thunderstorm risk. While two such wind-related regional hazard models may each be supported by the availability of significant historical event data, they may also make use of very different modeling approaches.[5] This process of building distinct hazard models suffers from the disadvantage that each model requires great investment and development effort, and as a result is not easily scalable across regions. Furthermore, because distinct models for related hazards may be developed using different methodologies, there is a lack of consistency across models. This lack of consistency also limits

[5] One must distinguish historical *event* data, such as a record of observed or reported thunderstorm events, from historical weather data (in this case wind measurements) which will also capture non-storm wind conditions.

scalability, or the ability to adapt a specific regional model for application to another geographical region.

The natural hazard risk modeling approach taken in this project introduces a significant innovation on the existing catastrophe risk-modeling paradigm. To overcome both the limitations of geographical scaling and modeling consistency, this novel approach involves the use of *modeled* historical weather. That is, high-resolution daily weather, simulated using state-of-the-art numerical weather models. Whereas most commercial catastrophe risk models rely on historical event data observations or measurements, which vary greatly in length and quality across different geographies, this new approach takes advantage of advances in global climate modeling to use simulated weather data which is consistent across the globe.

Not only do historical observational records of weather vary greatly in length, completeness and accuracy across countries, they also vary across time as measurement practices and technology has changed. In many low and middle income countries, historical weather data is simply not available in any meaningful way. When available, historical data is also limited in terms of the areas covered and spatial interpolation techniques must be used to estimate the value of weather variables between observing stations. Modeled weather data, on the other hand, provides a consistent record of weather at significantly higher spatial resolution on the basis of consistent scientific weather models.

The use of modeled weather generated by globally consistent climate models represents a significant step change in the potential for natural hazard risk transfer. It avoids the need to rely on often unreliable or limited historical data and furthermore, allows for a consistent risk modeling methodology across weather hazards and geographical regions.

Description of the Morrigu™ Platform

The modeling platform used to generate the modeled, historical, weather data or ‘climatology’ used as the basis for risk quantification in this project is referred to as Morrigu™. Morrigu™ was developed by Enki Research (a division of Enki Holdings LLC) based in Savannah, Georgia.

Morrigu™ is a modeling platform in the sense that it represents the innovative integration of multiple hazard modeling components, data sources and data processing components, which together allow for the generation of simulated historical weather (wind, temperature, precipitation and derived variables such as soil moisture) as well as the assessment of event risk and related economic impacts. While some of Morrigu’s™ components are proprietary to Enki Research, the platform is designed to interface with well-known third-party numerical weather or global climate models. This ability to make use of well-understood peer-reviewed public domain models is very powerful and offers a level of transparency and credibility that could not be matched by an entirely proprietary model or suite of models.

Annex C presents a high-level, conceptual, overview of the Morrigu™ platform. The most pertinent component of Morrigu™ to this grant work is the ‘Weather Generation Interface’, shown as a blue box. This is the component of Morrigu™ that interfaces with external numerical weather models (depicted by the yellow box on the bottom left). The purpose of the Weather Generation Interface is to receive weather data that is simulated by an external model, process that data, and feed it to a downstream Morrigu™ component, thus driving the simulation of other weather-dependent phenomena. For example, the Weather Generation Interface may receive precipitation input from the external weather model, and use it to drive the hydrology model, which in turn simulates hydrological processes to characterize flood risk.

Morrigu™ is an extremely versatile platform thanks to its ability to integrate third-party natural hazard models. Numerical weather and climate models are very complex simulation tools, reflecting state-of-the-art scientific research. Because of the complexity of the physics underlying weather dynamics, different models developed by different teams of scientists usually reflect different sets of assumptions, resolution and reliance on different input data sets. Because of these differences, model choice is critical for any given application – and the flexibility of being able to swap weather model in Morrigu™ is very powerful.[6]

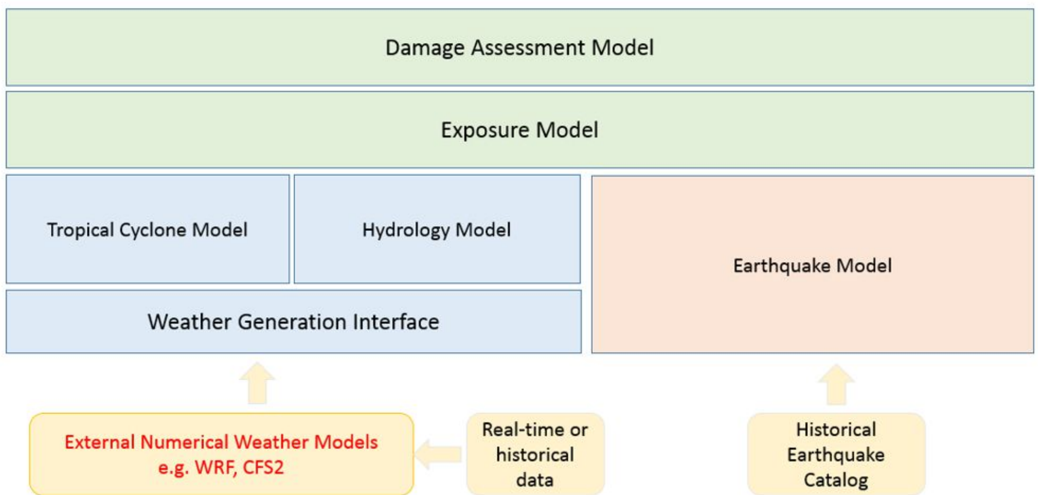


Figure 6.1 - Conceptual architecture of the Morrigu™ natural hazard modeling platform.

The application of Morrigu™ to this project revolves around seven weather variables. Four base variables include minimum and maximum daily temperate, average daily precipitation and maximum daily wind. Three derived variables include daily soil moisture, daily cold hours and daily heat stress index values. Together, these variables allow for the assessment of risk related to hazards, such as drought, excess rainfall and heat stress.

For the purpose of this grant work, and after extensive consideration of numerous alternative models and associated data sets, the numerical weather model selected to simulate daily weather was the US National Weather Service's Climate Forecast System version 2 (CFS2, Saha et al. 2014).

Spatial Dimensions of the Data

Numerical weather models generate very large amounts of very detailed data, representing the detailed physics of the weather processes being simulated. Furthermore, this data is often

[6] An extensive overview of climate modeling, numerical weather simulation, and the Morrigu platform capabilities is included in Annex C.

generated over very fine space and time resolutions which require some level of aggregation that is more relevant to the particular application at hand.

As mentioned above Morrigu™ was configured to utilize the US National Weather Service's CFS2 global climate model to simulate weather. The CFS2 model is global in scope and operates at a spatial resolution of 0.205 degrees. This is equivalent to a grid of cells, each with a roughly 30 km radius. Each of the 24 countries included in this study, is essentially represented by a grid of cells (of 30 km radius), upon which computations are performed at every time-step in the simulation process.

The final, post-processed, daily weather data generated by this study is presented at the first level administrative unit level based on a third-party source. Here, the GIS polygons are obtained from Natural Earth, and are fully in the public domain.[7] First-level administrative units represent the first level of political boundaries within a nation (e.g. state or province), and as a result their geographic extent depends on the specific country in question. There are 871 distinct administrative units across the twenty-four countries covered. Figure 6.1 provides a reference map of administrative units and index system for Cambodia, as an example.

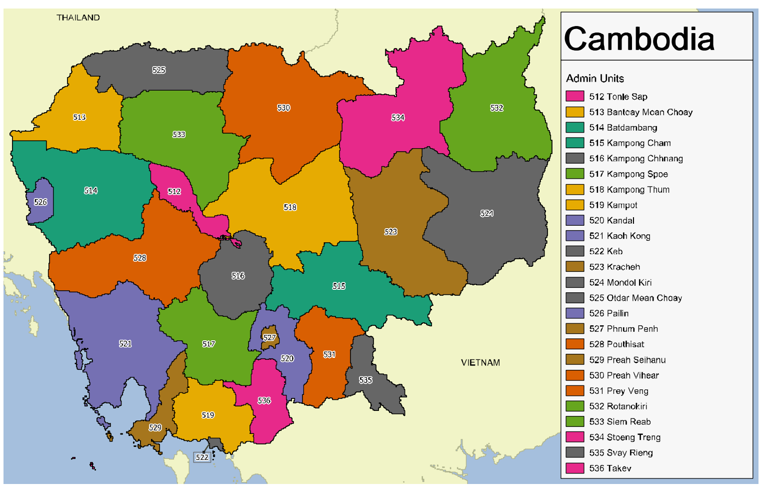


Figure 6.1 - Administrative areas for Cambodia.

Data Catalogue

The data generated for the purpose of this project covers 24 countries (Table 1) and includes daily time series (i.e., climatology) for seven primary variables (Table 2) over the period 1979–2015. These 37 years of daily weather data represent a consistent modeling methodology based on the operation of the CFS2 climate model. These data were subject to an initial data quality assurance process, described in Annex D. Along with the numerical data are supplemental GIS polygons that allow for mapping and visualization of the climate data, and prepared reference base maps for the countries included. Finally, these data will be made available for non-commercial open access, the objectives and details of which are contained in Annex I.

[7] http://www.naturalearthdata.com/about/terms-of-use/

Table 1 - Countries for which climatology data was generated.

Armenia	Honduras	Mongolia	Rwanda
Bolivia	India	Myanmar	Sri Lanka
Cambodia	Kenya	Nigeria	Tajikistan
Ecuador	Kyrgyzstan	Paraguay	Tanzania
Ethiopia	Malawi	Peru	Uganda
Georgia	Mali	Philippines	Zambia

Table 2 - Weather variables simulated by Morrigu™.

Variable	Units
Maximum wind speed	meters per second
Daily total precipitation (rainfall)	millimeters
Soil moisture fraction (upper 25cm soil layer)	unit-less fraction
Daily peak temperature	degrees Kelvin
Minimum daily temperature	degrees Kelvin
Daily number of hours below freezing	hours
Heat stress index	degrees Kelvin

Section 7: Step 3 Constructing FDRM Solutions for Recovery Lending

The first component of the FDRM system is the definition of the basic index contract structure used to calculate the payments (loss cost) for a given peril over a defined time period and geography. For these analyses, it is the first level administrative areas within a country that represents the primary insured unit, as well as the unit of observation of the weather variables provided by the Morrigu™ platform.

While the insured unit is the administrative unit, the individual loss cost values arising from the index contracts are aggregate to provide a *country level index* that is then used in the financial modeling to develop ex-ante systems for releasing liquidity and capital that are proportionate to the severity of the event. This section outlines these initial contract structures that feed into the FDRM financial modeling component.

Three perils are of primary interest in the design of disaster risk index contracts for MFI networks and investors:

- Excess precipitation
- Windstorm / tropical cyclone winds
- Pervasive drought

The Morrigu™ platform provides daily weather and derived variables used to index each that are applied to a contractual structure that provides a series of payments based on exceeding a specified threshold.

The initial calculation of the index loss cost for access to credit follows the same linear function based on pre-defined entry and exit thresholds given the index. The entry and exit thresholds are defined on the basis of estimated return periods, or the average length of time that one would expect to observe for an event of certain intensity. Return periods here are not estimated directly from the data given the length of the time series, but rather from the theoretical exceedance probability and applied to the weather index to define the levels corresponding to that return period. For instance, an event that is expected to occur once in ten years will have a 1/10 = 10% chance of being exceeded in any single year. Having the percentile (probability) of interest, the level associated with that percentile is found empirically and used to compute the loss cost for that peril.[8]

For the risk transfer product which supplies the capital needs, loss cost values are often computed for the risk transfer component using an attachment at 1-in-10 years and exit at 1-in-100, whereas the credit component can take on a number of different threshold values depending on particular institutional needs, discussed further in their respective sections. The manner in which these results are incorporated into the overall FDRM system is described in detail in section 8. Figure 7.1 provides a generic example of the payment structures for credit and capital.

[8] The majority of analyses are performed using the R statistical language and environment (http://www.R-project.org/). For much of this report, the quantile function is applied to compute the levels given a probability.

Figure 7.1 - Example of FDRM payout structure for credit and capital.

Administrative Unit Exposure Aggregation

Calculating raw loss cost values on the basis of a weather index across administrative units is adjusted to reflect the relative contribution of each when aggregating to the country level. The aggregation weighting scheme adopted can take a number of different forms, depending on the intended purpose and features of the landscape. Regardless of the method used, the weights across administrative units must sum to unity.

- *Equal weights*. The naïve approach is to equally weight each administrative unit (1/n), regardless of size, economic, or food security contribution. This method over attributes impact coming from smaller administrative units.
- *Area weights*. A weighting index based on the relative spatial size of administrative units. This can be used as a useful reference to compare against other weighting methods, to show how different allocations alter the relative risk and aggregate loss cost.
- *Production weights*. Useful in a food security context, this places more emphases on areas providing greater contribution to countrywide agricultural (or other resource) output. In this report, production weighting is performed on the basis of cultivated crop production, and so excludes the contribution of pastoralist system to food (in)security.
- *Portfolio weights.* A weighting index based on the proportion of a lender's overall loan book in a particular administrative area. The intent is that the weights reflect relative greater or lesser vulnerability to the institution's financial viability across geographic areas. Portfolio allocations must be examined in light of potential seasonality of lending, other anticipated changes in portfolio composition, and expectations of vulnerability.

Throughout this report, portfolio weighting is the method used to balance relative risk across administrative units when aggregating loss cost values to the country level. Those areas with a higher proportion of the loan book are presumed to be more exposed to risk, though this is not a complete proxy as variation in loan and client type and location within an administrative area do influence vulnerability.

Loan book information collected in conjunction with VisionFund and Blue Orchard Fund are used in the construction of a weighting index and applied to the countries and institutions associated with each. The spatial quality of loan book information can vary considerably, and rarely are the locations of client's economic activity mapped during the lending process. Where this is done, as in the example of Cambodia to follow, accurate and reliable weights can be achieved. As more often is the case, loan book information is available only at the branch office or even less granular level. The service area of different branch offices may overlap and clients' and branch locations may be based across administrative boundaries. In these cases, various assumptions must be made regarding the means to attribute the loan book to administrative units, including the average service area distance, loan size, etc. to complete the analysis. Annex F provides detail of the methods and assumptions employed to parse out a loan book that is available only at the branch level.

Portfolio Exposure: Case Study of VFI Cambodia

The recent VFI Cambodia loan book information is highly detailed regarding the type, timing, and location of individual loans in the overall portfolio. Individual loans are geographically referenced based on a consistent system of village level identification numbers. To create the initial weighting index, the village level locations can be accurately geo-referenced to a specific administrative unit, regardless of the which branch office they are associated with, and aggregated to find the proportion of lending in each administrative area. In the initial allocation, current outstanding loan book values were used for the month of December 2015.

To examine the effectiveness of the weight-derivation methodology within the index design, with respect to agricultural and non-agricultural loans, and the possibility of seasonality affecting the proportional allocation, the entire loan portfolio from January to December 2015 was further examined. This data showed that, despite the examined book being around 70% agricultural, seasonal trends in lending were not significant enough to significantly alter the geographic distribution of the loan book across the year.

Therefore, for risk transfer product terms of one year or thereabouts, fixing the relative importance of each admin unit within the index (used to trigger the financial product) at the point of product inception would not reduce the effectiveness of the risk transfer product across the year. This portfolio analysis demonstrated that the chosen methodology for setting relative geographic weights within the FDRM index is fit for purpose for Cambodia. However, further analysis would need to be undertaken to determine the appropriateness of this methodology for other countries.

Figure 7.2 below shows the portfolio growth across the year for the modeled Cambodia loan book, for both agricultural, and non-agricultural loans. Although the rate of growth does vary, the variation is not significant enough to alter the pattern of steady growth across time.

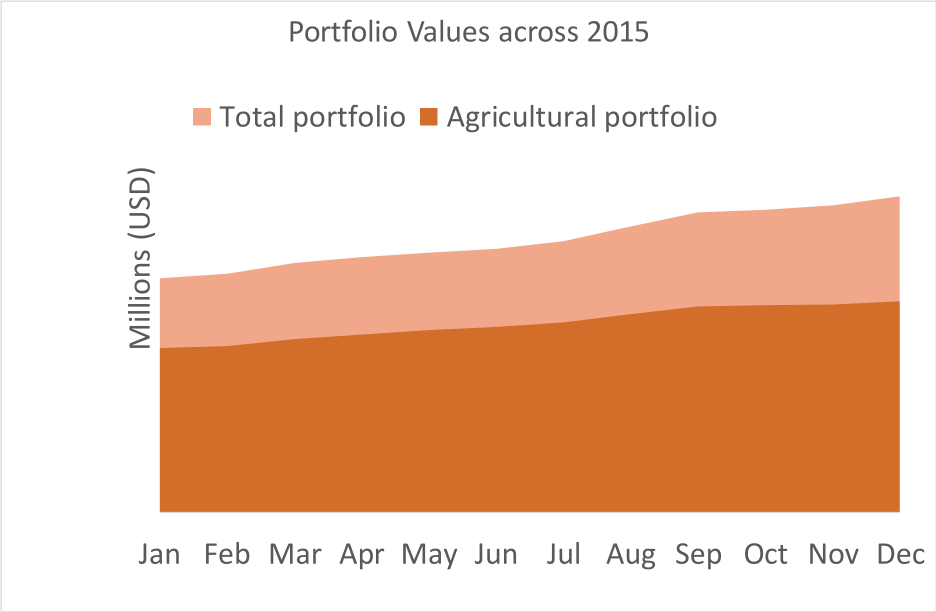


Figure 7.2 - Seasonality of the modeled Cambodia portfolio.

Figure 7.3 Further demonstrates this stability. These maps show the concentration of the loan book across administrative units for June and December of 2015.

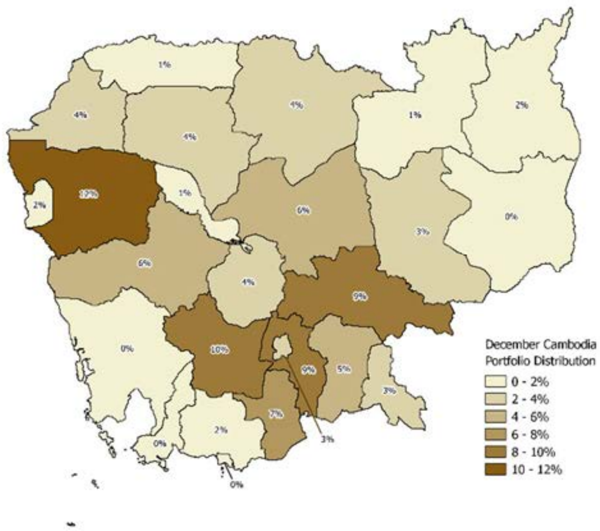
Exposure Weight Modifications

The exposure weights as described above impact how the index contract structure aggregates from the administrative level to the country level. For an MFI network owner or investor, the portfolio method applies more emphasis on those areas with greater concentration of overall lending activity and which is anticipated to remain reasonably stable over the life of the FDRM contract (usually 12 months). However, there may be instances when an end user of the FDRM system, using additional information, will want to apply non-uniform adjustment to the exposure weights.

One example as indicated above may be when the loan book is subject to strong seasonality due to the maturity cycle of agricultural loans. While not appearing in the previous example, it could have the effect of underrepresenting those areas having high, and potentially more vulnerable, agricultural activity and justifying the reallocation of the portfolio weights. Loan type differentiation more generally could expose the possibility of pockets of greater vulnerability based on either the loan type or even client type given sufficient distinguishing data.

Anticipation of rapid loan growth and other restructuring activities may also compel the network owner or investor to consider reallocation weights into those areas anticipating high growth, and away from those areas that are in phase out. There may be instances where lending activity in a well-defined area is protected by some alternative risk transfer mechanism or guarantee, enabling a shift in portfolio weights away from that area to avoid redundancy. This could occur, for instance, through a tie-in with a development project or lending to larger-scale enterprises that privately chose some type of default or business interruption protection.

Finally, some administrative areas may host a small fraction of the overall loan portfolio such that potential disaster liquidity problems as well as potential, but likely small-scale, recovery lending could be managed using precautionary resources.



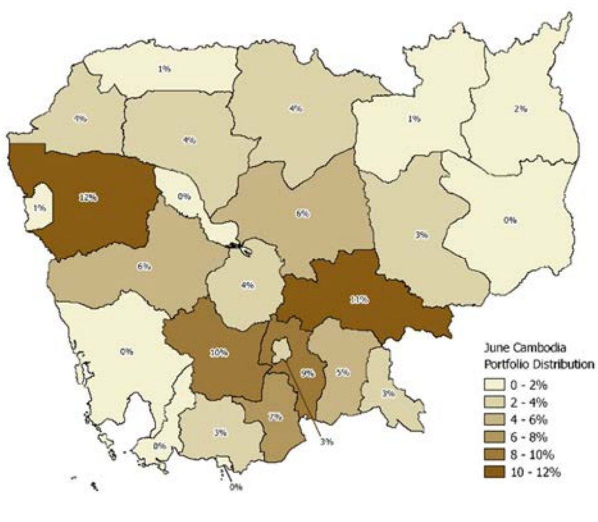


Figure 7.3 – December portfolio distribution (upper), June portfolio distribution (lower).

Excess Precipitation and Extreme Wind

The structure of the base index contract for excess precipitation and extreme wind is the same at this stage of the analysis and so are described together here.

The Morrigu™ platform provides daily observations of cumulative rainfall and peak wind speed for each administrative unit. Natural disaster risk associated with excess precipitation and extreme wind events are usually associated with tropical storms. Interestingly, it is observed that many tropical storms either bring torrential rainfall, because they are slow moving, or severe damage due to high winds, but usually not both.

The index structure for excess precipitation and extreme wind speed that capture the idea of tropical storm damage is organized on the basis of a *daily* contract for each administrative unit but which accumulates throughout the year. However, as with any index-based contract, it is important to be clear about what events trigger payments and what does not. For this configuration, problems arising from excess precipitation can be thought of in terms of rapid inundation due to local rainfall. It does not index overland or riverine flood that originates from non-local precipitation, although the territorial effect of the administrative unit may capture water movement within its geography. Similarly, the precipitation index does not capture flooding that results from more rapid than usual spring snowmelt. However, because the contract accumulates daily, the structure will naturally capture precipitation events that span multiple days, but without explicit parameters on the length of aggregation. For the index of wind speed, the focus is on the direct consequences of extreme damaging winds and not, for example, storm surge that can arise as a consequence. A discussion pointing to a number of potential alternative techniques and systems for addressing these perils is provided in the concluding sections directing future work.

Contract Mechanics

The wind speed and precipitation indexes operate on the basis of daily maximums throughout the year, aggregating administrative unit loss cost to the annual level, then across all administrative units to find the country annual loss cost value, conditioned by the administrative unit weighting index.

Because the contract is organized on a daily basis, the determination of the return period probability is modified before finding the entry and exit thresholds. That is, annual probability for a 1-in-10 year event entry threshold is simply 1-1/10 = 0.9 whereas the daily probability is found as 1-1/(10*365.25) = 0.9997262. The adjusted probability is then used to find the payment triggering entry (and exit) levels of the daily observations.

The result is a set of 365 daily index contracts based on the linear proportional payment structure. The daily payments are summed across the year, adjusted by the administrative unit-weighting index, and aggregated to find the country level annual loss cost. In notation:

$$Country\ Loss\ Cost\ = \sum_{i=1}^{N} WI_i \sum_{j=1}^{365} \frac{I_{ij} - P_{A_{ij}}}{P_{E_{ij}} - P_{A_{ij}}}\ , \forall\ P_{A_{ij}} < I_{ij} \leq P_{E_{ij}}$$

where,

i is the country administrative unit index,

j is the weekly index,

I is the daily wind speed/precipitation observation,

WI is the weighting index for administrative units (by portfolio),
P_A is the attachment level for probability of 1-in-10 year return period, and
P_E is the exhaustion level for probability of 1-in-100 year return period.

Contract Assessment

The proceeding contract design computes administrative unit daily loss cost values for a set of entry and exit return period thresholds and aggregates them to the country level on the basis of a weighting index. While there are several choices, the weighting index throughout this report for a microfinance network owner or investor is based on the percentage of portfolio present across the administrative units.

provides an example of the country level loss cost values for excess precipitation and wind speed over the thirty-seven years of data for the Philippines, rounded to the nearest percent.

Comparing loss cost results with reports of extreme events must be viewed in light of an MFI's portfolio distribution. A severe event affecting some portion of a country having relatively small portfolio exposure may give the impression that an event has been missed by either the underlying Morrigu™ weather data or the contract structure. In addition, because the contract is calculated at the administrative level and aggregated, it is possible, though not common, to have a loss cost result in excess of 100 percent. Limits are imposed in such cases during subsequent financial modeling where a step function is imposed on the series.

A number of important past events can be identified from the perspective of an MFI's current portfolio distribution. These include:

- Typhoon Mike, November 1990.

A Category 5 typhoon, that made landfall over easterly areas of the Philippines with 140 mph winds and heavy rainfall that triggered extensive landslides. This event would have triggered and FDRM payment of 10% of sum insured based on rainfall and 28% based on wind speed.

- Typhoon Haiyan, September 2013.

Also Category 5, Typhoon Haiyan had the highest one-minutes sustained wind speeds ever recorded at landfall at 196 mph. As a fast moving storm, it delivered less rainfall but rather a strong storm surge that inundated some coastal communities. The wind speed trigger would have paid at 110% of the insured limit while the precipitation trigger would have released nearly 40% of the insured value.

- Typhoon Winnie August 1997.

This very strong event first brought wetter than usual conditions during June-August, which combined with typhoon Winnie, would have resulted in a 20% precipitation payment. Thereafter strengthening, a severe drought impacted much of the Philippines resulting in widespread crop and aquaculture failure. The risk transfer product would have paid 40% of the sum insured for drought in 1997 and 100% in 1998.

Table 7.1 - Philippines: example modeled loss cost values for excess precipitation and wind speed, 1-in-10 year attachment, 1-in-100 year exhaustion, in percent of sum insured.

Year	Precip	Wind	Year	Precip	Wind
1979	24	0	1998	7	0
1980	0	0	1999	1	0
1981	0	4	2000	0	0
1982	0	0	2001	0	0
1983	0	0	2002	0	0
1984	8	0	2003	0	0
1985	0	0	2004	0	0
1986	3	0	2005	0	0
1987	16	0	2006	0	0
1988	0	0	2007	0	0
1989	20	0	2008	7	0
1990	0	28	2009	0	0
1991	10	0	2010	0	0
1992	0	0	2011	27	0
1993	0	0	2012	12	20
1994	14	0	2013	45	110
1995	0	1	2014	25	13
1996	0	2	2015	7	23
1997	0	0			

Drought Risk Transfer Product[9]

Understanding the Consequences of Drought

Drought is a slow-onset event with no clear beginning and, in many cases, no well-defined ending. Intermittent precipitation during a drought, while always welcome, may prove to be little more than a brief reprieve providing only superficial ‘green up’ of plant life. Droughts can span multiple growing seasons, compounding problems and creating challenges for the economy and for those delivering financial services to the poor. The consequences of drought in low and middle-income countries can be dire.

In most low and middle-income countries, a large percentage of the rural poor still depend on agriculture and related activities for their livelihoods. And while the portfolios of the poor and vulnerable generally involve a good blend of income sources, a widespread drought can negate even the best diversification strategies, because it creates losses across many otherwise uncorrelated income sources and savings. For example, the rural poor typically use livestock as a form of savings as well as a revenue generating investment. During a drought they ‘collect’ on

[9] Of some importance, the drought work being performed under this grant was also used as a match for a grant from the Hummanitarian Innovation Fund http://www.elrha.org/hif/home/ to advance some work with the UK-based start network on food security and drought.

their savings, but their neighbors are doing the same, which creates downward pressure on price and reduces the value of their savings. In addition, they are losing potential future income from the asset.

Widespread drought creates many related problems beyond those who are farming or in pastoralism. Income from non-farm sources will also suffer as jobs in rural communities are linked to the well-being of the agricultural sector. More importantly for the poor, drought will cause spikes in food prices. From a food security perspective, the working poor generally spend 70 percent or more of their disposable income on food. A pervasive drought that is concentrated in agricultural regions will spike food prices, easily doubling the cost of food throughout the country depending on market integration.

Major droughts have a very large foot print, and such highly correlated risk events are typically uninsurable for any insurance company operating within the confines of a single country. Insurance performs best when the insured events are largely independent. Pooling independent risk allows for relatively small premiums to pay for large individual loss (e.g., life insurance, auto insurance, etc.). Under these conditions the variance of the pool will always be less than the variance of the individual risk.

In addition, drought can create significant business interruption for microfinance institutions. The consequences described above of a catastrophic drought will affect the best strategies of those lending to the poor in low and middle-income countries. While the classic portfolio strategies of diversification by lending to different sectors and among different regions of the country are certainly prudent, the impact of a prolonged and widespread drought can reduce the effectiveness of these strategies.

Modeling and Insuring Against Extreme Drought

The core objective is to design a risk transfer product for those lending to the poor that will effectively hedge against the widespread business interruption consequences of a major drought. Drought has two important characteristics – severity and duration. Severity refers to the magnitude of the moisture deficit at a point in time. A drought may be underway when rain is at historically low levels during important time periods (e.g., flowering of major crops). Duration measures of drought can capture the slow onset dimension that involves the cumulative effect of having shortfalls of precipitation for a number of years.

Most drought index insurance contract designs focus on rainfall levels *within* the growing season. By breaking up the plant growth cycle into critical time periods and developing contracts that pay based on shortfalls of rain during planting or flowering and surplus rain at harvest, any number weather index insurance contracts have been designed for farming households in low and middle income countries (Hess and Syroka 2004). Variations of these approaches continue for farmers and even for sovereign drought risk (African Risk Capacity).

If data are available, parametric risk transfer products for *within* season variations of rainfall can be designed. However, while designs that focus on rainfall within the season can capture a number of problems, simply focusing on precipitation within the growing season may not be adequate in capturing *duration* of a drought. If the drought conditions have been prolonged (duration), simply considering rainfall within the season may not be adequate. Having just enough rain on very dry soils that misses the trigger for an index-based risk transfer product using rainfall deficit may not promote conditions needed to have a successful growing season. An additional potential problem rests with the confounding effects of soil conditions, in particular soil organic carbon content, that impacts moisture retention which that can lead to drought-like conditions even when rainfall is seemingly sufficient. Where soils are severely degraded, measures of precipitation will not be a good proxy for drought (Hartell and Skees 2009).

An alternative that has potential to compensate for the problems tied to focusing only on within season measures of rainfall involves indices derived from earth observation measurements of vegetative greenness (e.g., NDVI). If these measures can capture the entire season, they could be designed so that they avoid the problem of having a bit of rain at the critical time that does not result in a good agricultural outcome. Nonetheless, even these systems can give false positives when light rains create a temporary flush of vegetative growth (Turvey and McLarin 2012). A number of other challenges accompany vegetative greenness measures to capture drought:

- Greenness can be non-agricultural (weeds, shrubs),
- These indexes work best with monoculture cropping and grassland systems,[10]
- Limited data series only beginning in the 1970s at the earliest.

Soil Moisture as an Alternative Index

The limitations of rainfall and vegetative greenness measures used to indicate drought have led to our efforts to focus on soil moisture conditions as a promising alternative. Soil moisture conditions can capture both severity and duration of a drought when the calculations build upon the previous year's climatology, as has been implemented in the Morrigu™ and described in the earlier data section. To recap, the Morrigu™ soil moisture variable is defined as gravimetric water content, the fraction of water to soil by weight in a meter cube, expressed in Kg/Kg. This soil moisture fraction ranges from 0 when completely dry up to 1, but depends on soil type porosity. For full details, please refer to the Morrigu™ data catalog in Annex I.

Soil moisture estimates can be developed across several different soil profiles (depths). For instance, a soil moisture index can be developed for drought in predominant cropping systems using the upper layers of the soil profile, whereas predominantly pastoral regions may use the deeper layers of the soil profile to develop the index. Additionally, soil moisture can be used to capture drought in countries having bimodal cropping seasons (e.g., some regions of Ethiopia and Kenya). If soil moisture estimates can be matched to the importance of crop/pastoral growth throughout the year, a drought index that performs better than one measuring only within season rainfall or one measuring vegetative greenness should be possible.

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[10] Satellite images are being used in Kenya and Ethiopia for drought induced livestock mortality (Mude et al. 2010; Vrieling et al. 2014).

As part of the Morrigu™ validation process, soil moisture estimates were compared with observed vegetative greenness measure for several countries. Early results were not encouraging. Recognizing that most researchers who make estimates of soil moisture reinitialize initial conditions each year and knowing that the duration of a drought is important, the system was restructured to allow all of the previous year's soil moisture measures to feed into the current year. The correlation between soil moisture and vegetative greenness indexes improved considerably (i.e., in the 90 percent ranges) once the soil moisture history was allowed to inform current conditions.

The Morrigu™ platform currently provides daily estimates of soil moisture using the complete climatology back to 1979. Daily values, which can be quite volatile, are smoothed to the weekly average and represent the underlying historical basis for the drought index, and provide 37 years of observations (1979–2015).

Just as with cumulative rainfall or vegetative greenness, estimates of soil moisture can be averaged over the available record for each week to reveal the seasonal patterns for different regions. Figure plots the mean weekly vegetative productivity index (VPI) and soil moisture for administrative units across Kenya. Kenya will be used to illustrate the processes to gauge drought with soil moisture indexes. These plots clearly show the bi-model patterns of soil moisture that match the cropping systems of Kenya. The plots also show good correspondence between measures of vegetative greenness and soil moisture estimates. To illustrate the seasonal variation of soil moisture over the record, Figure plots the data around the mean values for each of Kenya's administrative units.

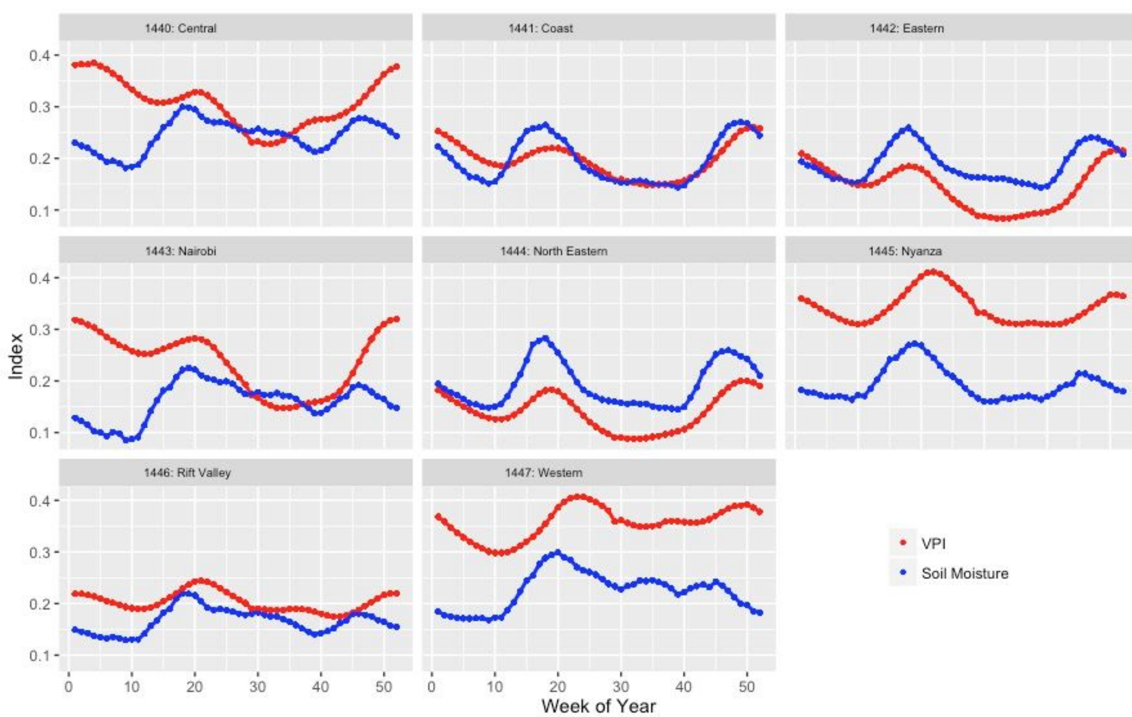

Figure 7.4 - Kenya average soil moisture and VPI indexes.

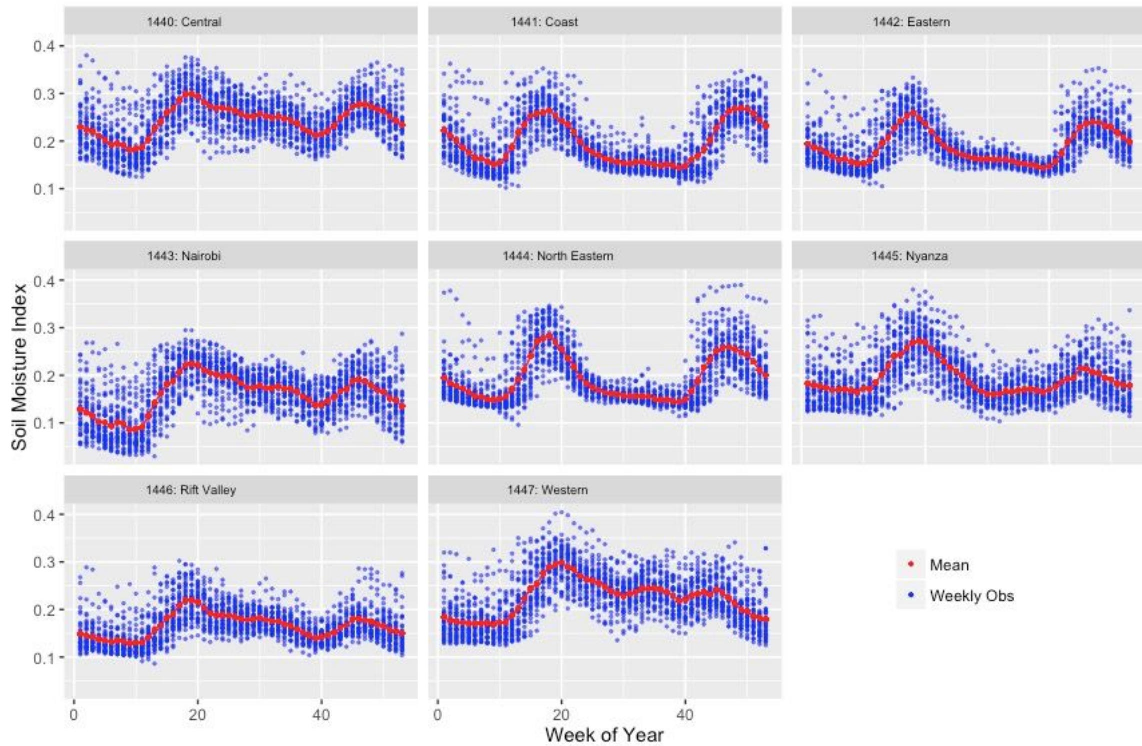

Figure 7.5 - Kenya soil moisture variation.

Drought Index Contract Design

Several drought index-based risk transfer products were developed and tested. One included a relatively complex design that presented the depth (severity) of the problem by week during the cropping season and then summing across weeks to give the view of severity and the duration of severity during the growing season by administrative region. This approach could be further tailored to provide drought risk transfer products for specific geographies. However, for the purpose of designing a truly catastrophic risk transfer product for correlated drought, a countrywide approach was taken for establishing the soil moisture index and triggering thresholds.

The estimate of soil moisture compared to normal conditions contains information about severity and duration. These measures must be used in conjunction with some understanding of the seasonality of important productions systems (crop and pastoral) to complete the analysis. An agricultural crop bundle calendar is developed to identify when and to what degree aggregate agricultural production is most vulnerable to soil moisture deficit throughout the year. This calendar is used to condition the soil moisture values for construction of the country level index.

Crop Calendar Index (CCI)

The relative position of soil moisture during the vulnerable time periods will provide the most information about drought conditions that matter the most for society. GlobalAgRisk invested

heavily in developing a “Cropping Calendar Index’ (CCI) to provide appropriate weights for each week of the year to indicate when soil moisture contributes the most to agricultural outcomes. The data used to develop the CCI included the major crops in the region, the typical planting times, the crop schedule and the yield response to moisture.
The general steps in constructing the CCI are as follows:

1. Identify the typical production for up to 25 crops within the administrative unit;
2. Determine the typical planning date and map the growth cycle for each crop,
3. Estimate drought vulnerability for each crop throughout its growth cycle and weight each period for relative importance,
4. Aggregate the calendars of all the significant crops identified in the administrative area, weighted by the production contribution of each.

Details of the procedure for developing the CCIs are presented in Annex E.

This sequence provides a consistent methodology across all geographies and results in a monthly relative weight value for each administrative unit. For use with the soil moisture data, the calendar is unitized and spread across weeks of the year. Finally, the CCI is normalized so that the values for the year sum to one. This fixes a weight that reflects the relative ‘importance’ of each week of soil moisture. Weeks having no crops or very small values (off season activity) grown have weights of zero.

To illustrate, Figure 7.6 provides the plot of the CCI for administrative units in Kenya. This view of a crop calendar is different from a calendar for a single crop since it includes the time element of many crops within the region. Variations between regions are due to the different mix of crops cultivated, differences in the typical planting month, and differing share of crops in total production. While accommodating the full range of crops grown, the calendar also successfully captures the relative importance of crops within a bimodal production system identified earlier with vegetative greenness and soil moisture.

Concentrating on the most important values by removing the weeks where values are low can further focus the CCI. Here, a ‘trim’ value is defined and applied to the unit calendar by removing those values less than the trim. Figure presents the CCI values for the Kenyan administrative units using the trim value of 0.2. This allows one to eliminate weeks that are less important.

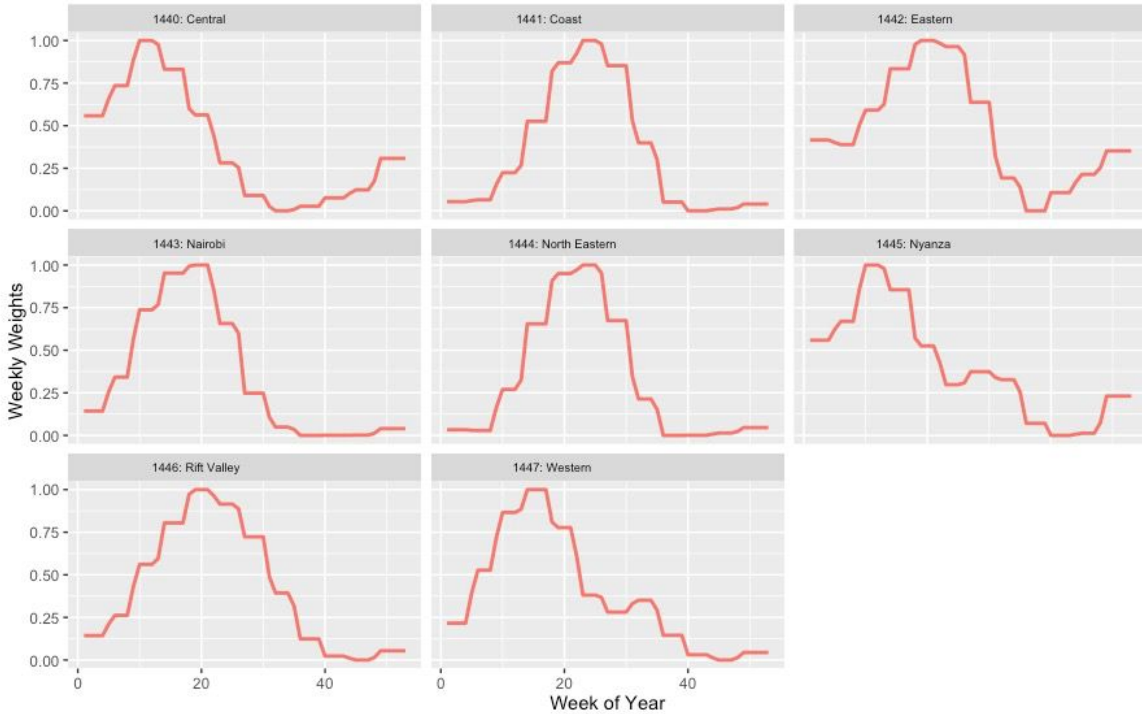

Figure 2.6 - CCI for Kenya.

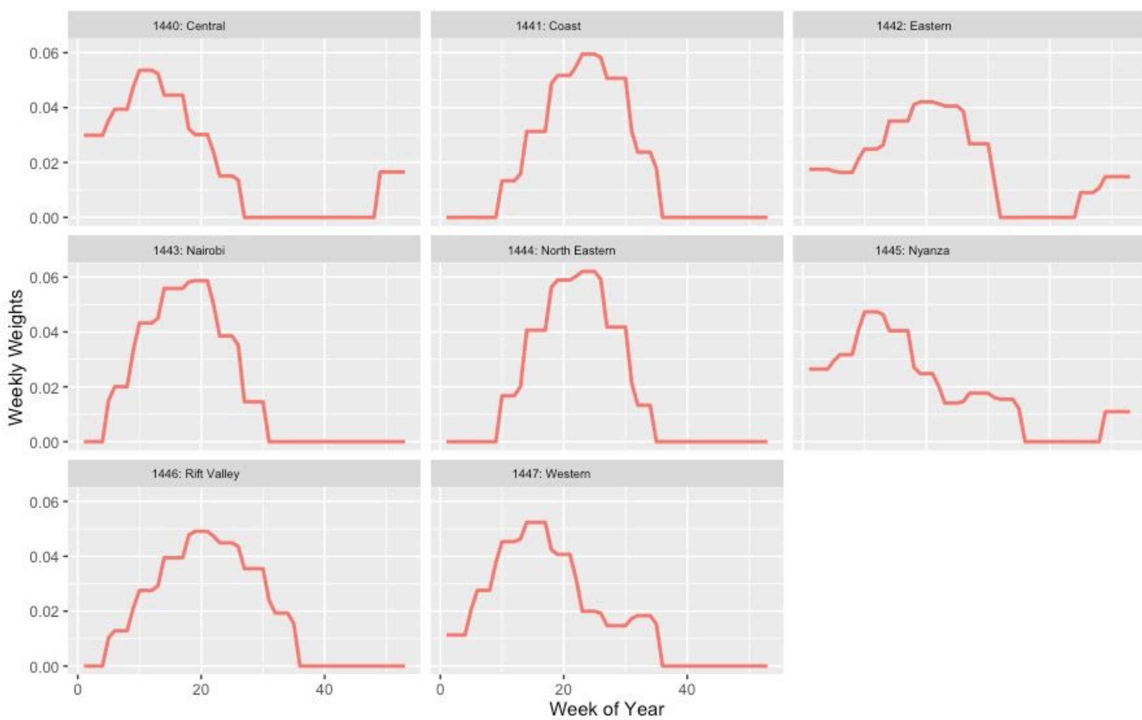

Figure 7.7 - CCI for Kenya that eliminates less important weeks in the cropping seasons.

Constructing the Country Drought Index

Given a CCI for each administrative unit, one has information and a weight to apply to the soil moisture values that reflects how important that week's soil moisture is for the region. By multiplying the weekly soil moisture measure by the CCI and summing over the year, a single number is created for each year and each administrative unit. This measure is referred to as the Administrative Soil Moisture Index (ASMI). Given that the entire year is captured, the ASMI captures severity and duration of soil moisture as tied directly to the important periods of crop growth. In notation:

$$ASMI_i = \sum_{j=1}^{53} SM_{ij} * CCI_{ij}$$

where,

- *i* is the country administrative unit index,
- *j* is the weekly index,
- *SM* is the weekly soil moisture value, and
- *CCI* is the weekly crop calendar index.

To calculate countrywide measure, the Country Soil Moisture Index (CSMI), multiply the ASMI by the relative importance of each administrative unit and sum to the country level. Here, relative agricultural production shares are used as weights in the CSMI. Alternatively, a Portfolio Soil Moisture Index (PSMI) can be calculated in the same fashion by using weights that reflect the value of microfinance lending by administrative unit.

With the current data, the CSMI is given then as 37 observations on which to calculate attachment and exhaustion levels for their relevant return periods and on which to apply the linear proportional contract. In notation, the drought index is given as:

$$Country\ Loss\ Cost_j = \frac{P_{A_j} - \left(\sum_{i=1}^{n} ASMI_i * AW_i\right)_j}{P_{A_j} - P_{E_j}}, \forall\ P_{A_j} > CSMI_j \geq P_{E_j}$$

where,

- *i* is the administrative unit index,
- *j* is the country index,
- *ASMI* is the administrative soil moisture index,
- *AW* is the administrative unit weight (production, portfolio),
- P_A is the attachment level for probability of 1-in-10 year return period, and
- P_E is the exhaustion level for probability of 1-in-100 year return period.

The results of the drought contract for Kenya using the CSMI (with trimmed CCI) are represented in Figure 7.8. The CSMI captures the most severe drought on record for Kenya when the long rains failed in 1984 (with more severe effects in neighboring countries where multiple seasons failed). The CSMI for 1984 is .1612, which is about 82 percent of the normal CSMI. Given the structure of the risk transfer product, the payout for this year would have been

100 percent for both production and portfolio weighting schemes. Some preliminary work using the Kenya CSMI and curve fitting techniques to estimate return periods suggest that 1984 was at least a 1-in-50 year drought. Kenya's long rain failure and drought in 2000 is also captured by the CSMI, where nearly 4 million people were in need of emergency food assistance. Here, the production-weighted index would have paid slightly more than the portfolio weighted index, a reflection of less portfolio exposure in heavier agricultural dependent areas. Figure 7.9 decomposes the loss cost values for 1984 to show the contribution of each administrative unit to the payment, weighted by production.

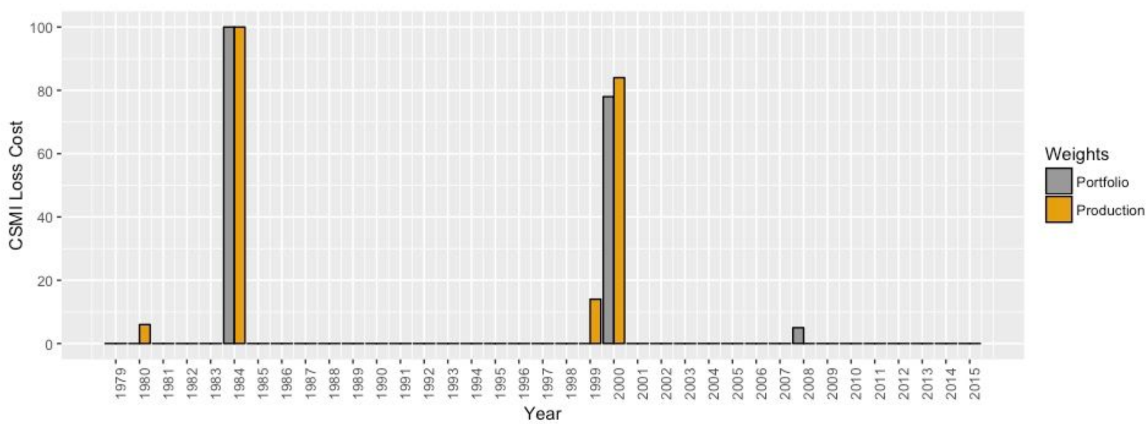

Figure 7.8 - Kenya CSMI loss cost 1979–2015.

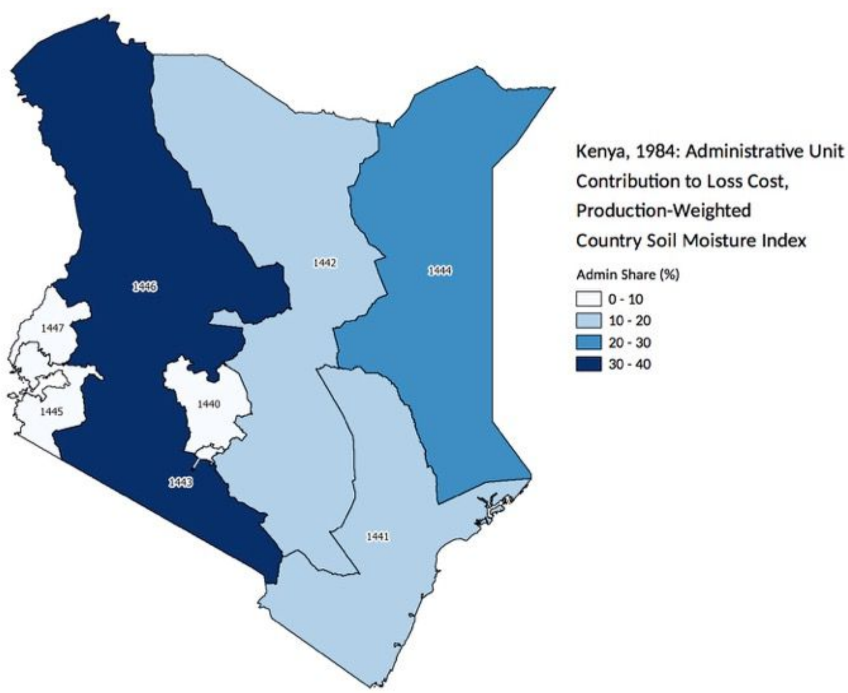

Figure 7.9 - Loss cost decomposition, Kenya, 1984.

A second illustration of the CSMI drought index focuses on Cambodia, a very different environment from the Horn of Africa. In Figure 7.10 the three most expressive droughts are 1994 and 2004, reportedly the first and second worst events in recent memory, followed by 1979. Here more pronounced differences are evident between the production and portfolio weighted CSMI aggregation methods, particularly for 1994. Figure 7.11 provides the loss cost decomposition for 1994. This case should be of particular interest in assessing the impact of potential food price increases relative to overall portfolio exposure to a lender's financial well-being.

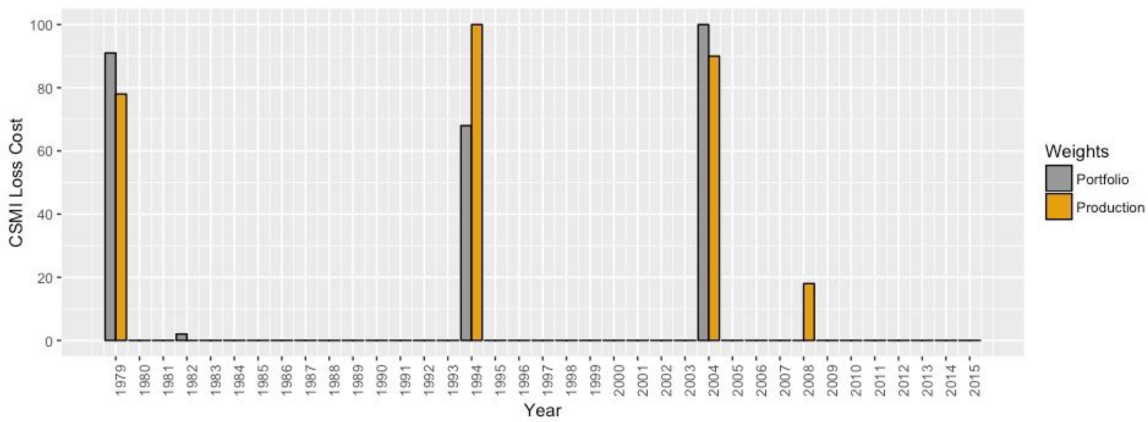

Figure 30 - Cambodia CSMI loss cost 1979–2015.

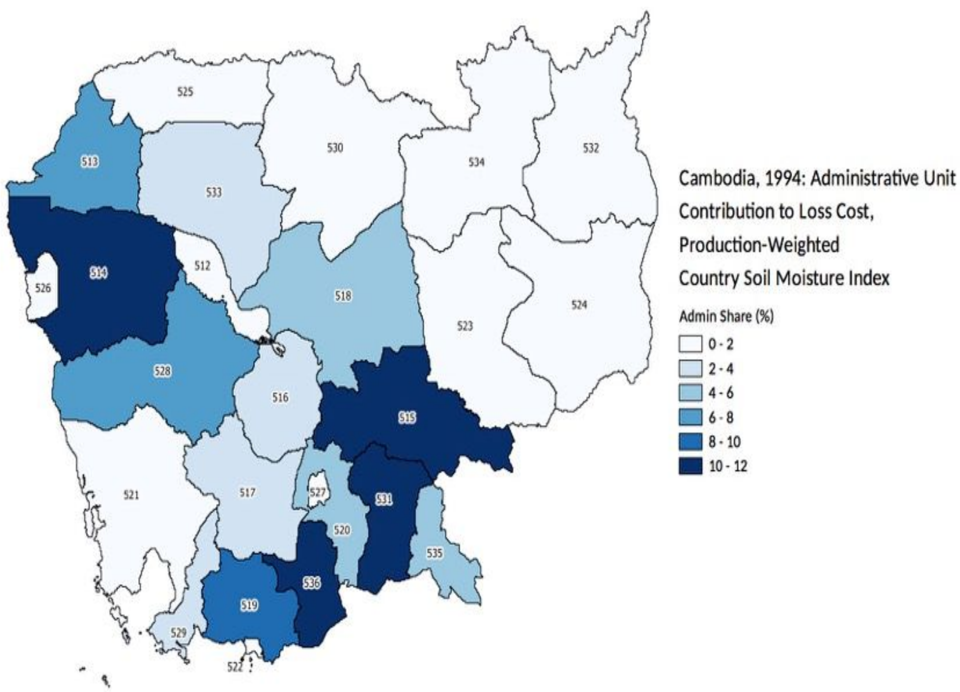

Figure 4 - Loss cost decomposition, Cambodia, 1994.

Risk Transfer Product Design Considerations

The initial risk transfer product designs for excess precipitation, windstorm and drought presented here do capture the signature of large catastrophic events of concern and provide a good benchmark not only in the initial modeling but also, as provided in the following sections, for illustrating the contribution the FDRM system can provide to risk management, financial stability and growth for MFI network owners and investors. Moving forward, investigation into a number of modifications are planned that should make the contract structure more responsive, robust and tractable.

Payment Frequency and Adjustment in the Financial Model

The annual loss cost values computed from the index contract are the starting point for a more customized financial modeling approach presented in the next section. In particular, because the extreme wind and rain contracts are built on the administrative unit as the insured unit, the country aggregation can result in a higher than desired frequency of modest payments. This outcome can persist even when increasing the return period attachment point at the administrative level. In order to achieve a final FDRM system design that is more aligned with a catastrophic risk transfer product, the financial model imposes a franchise deductible on the country level payouts that reduces payment frequency while maintaining the magnitude of payments needed following a catastrophic event. Future development work on these risk transfer products will seek to design a structure wherein return periods are assessed at the country level (instead of administrative unit) and therefore attachment points can be established based on country level return periods, similar to the drought product structure.

Other Methodological

Currently, the excess precipitation index is based on daily events that lead to the possibility of back-to-back payments for a rainfall-producing event that spans several days. While multiple payments may be administratively burdensome, a more interesting concern is how these payments are distributed relative to a payment structure that is designed to encompass a multiple day event. Contract structures will be explored that define a non-static event window to better capture the accumulation of 'slow moving' precipitation events.

The current drought risk transfer product structure uses the full year's soil moisture values to compute the index before calculating payment levels, if any, and is a feature of assessing a slow onset and developing event. However, given that there is value in mobilizing resources early and quickly, subsequent investigation will focus on the possibility of making partial payments based on mid-season values or even forecast values of soil moisture.

For extreme wind speed, moving towards a country level threshold structure will certainly reduce the overall frequency of payments and focus only on the larger events. A parallel investigation that is motivated by the same concern will focus on establishing damage-to-attachment return periods that could significantly improve the performance of the index. This analysis will require simulation and calibration within a well-populated damage model, a task that can be performed within the Morrigu™ platform in time.

Providing an estimate of the return period for a given event from the country level indices and resulting loss cost history can be useful for demonstrating to clients how the FDRM system responds, and can respond, under different scenarios, and is useful in financial model customization. Even with 37 years of data, which is normally considered an adequate record length for developing index-based risk transfer products, calculating reliable return period values using simple estimators is problematic. For example, the most extreme value in a data series of 37 years is unlikely to match a reliable estimate of 100-year return period value. These issues are explored in the technical Annex G that investigates statistically reliability using different statistical estimation procedures. In particular, a methodology that combines the best attributes of parametric procedures and non-parametric kernel smoothing procedures shows promise for this type of analysis.

Section 8: Prototype Portfolio Disaster Risk Management for an MFN

Building on earlier concept work on a financial disaster risk management system for VFI (VisionFund International 2015), VFI and GlobalAgRisk have designed a financial disaster risk management (FDRM) system to support post-disaster recovery lending, and to protect the balance sheets of MFIs in a modeled MFI network. The performance of this system has been modeled by GlobalAgRisk for a loan portfolio of $224 million spread across the 11 countries.

Ecuador; Honduras; Cambodia; Myanmar; Philippines; Sri Lanka; Kenya; Malawi; Tanzania; Uganda; Zambia.

This section outlines the FDRM system design, how it is represented in the modeling, and what the modeling concludes with regard to the performance of the system. *Please see the technical appendix for details of how key assumptions have been derived.*

The core objectives of the system that have been incorporated into the design are as follows:

1) Rapid release of liquidity to MFIs in the disaster-affected areas, to facilitate recovery lending for disaster events;
2) Rapid capital injection for MFIs in the disaster-affected areas for the more catastrophic disaster events, where MFIs are likely to experience capital erosion to:
    a. Restore the capital position of impacted MFIs with respect to the pre-existing portfolio of lending;
    b. Provide the additional capital required to support the expansion of the portfolio anticipated through recovery lending;
3) Cost-efficiency such that the system can be supported by an access fee charged to participating MFIs, which must be affordable in the context of their cost of borrowing.

To achieve all of the above, a system combining a mix of financial instruments has been conceptualized, comprising both a liquidity and capital response (see Figure 8.1). This is to accommodate the different system functions required, but also in acknowledgement of the fact that different financial instruments perform better for different layers of risk (World Bank 2011).

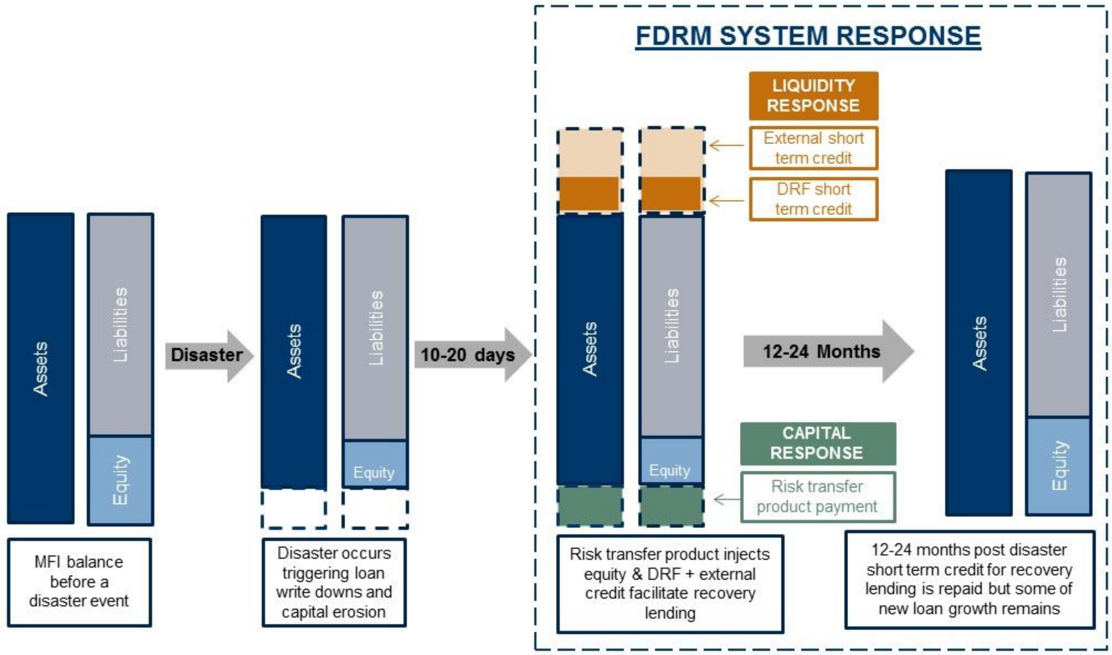

Figure 8.1. Conceptual view of MFI balance sheet under stress with and without FDRM.

System Design Overview

The conceptualized FDRM system comprises multiple components, as shown in figure 8.2 below.

At the **Local Level**, participating MFIs pay an annual access fee to a Disaster Recovery Fund (DRF) for access to the full FDRM response system (i.e. data services, risk transfer products and contingent credit). In the event of a disaster, the DRF releases debt and equity capital infusions as needed to impacted MFIs, to facilitate their recovery lending programs and to shore up their capital following any erosion that may have occurred.

At the **Global Level**, the provision of financing to the MFIs, and the liabilities arising from this, are managed through the Disaster Recovery Fund. The DRF will use three instruments to manage its contingent liabilities to participating MFIs:

1) A limited pool of its own **reserves**;
2) **Contingent loan agreements** with external liquidity providers;
3) A **risk transfer product** with a provider such as Global Parametrics.

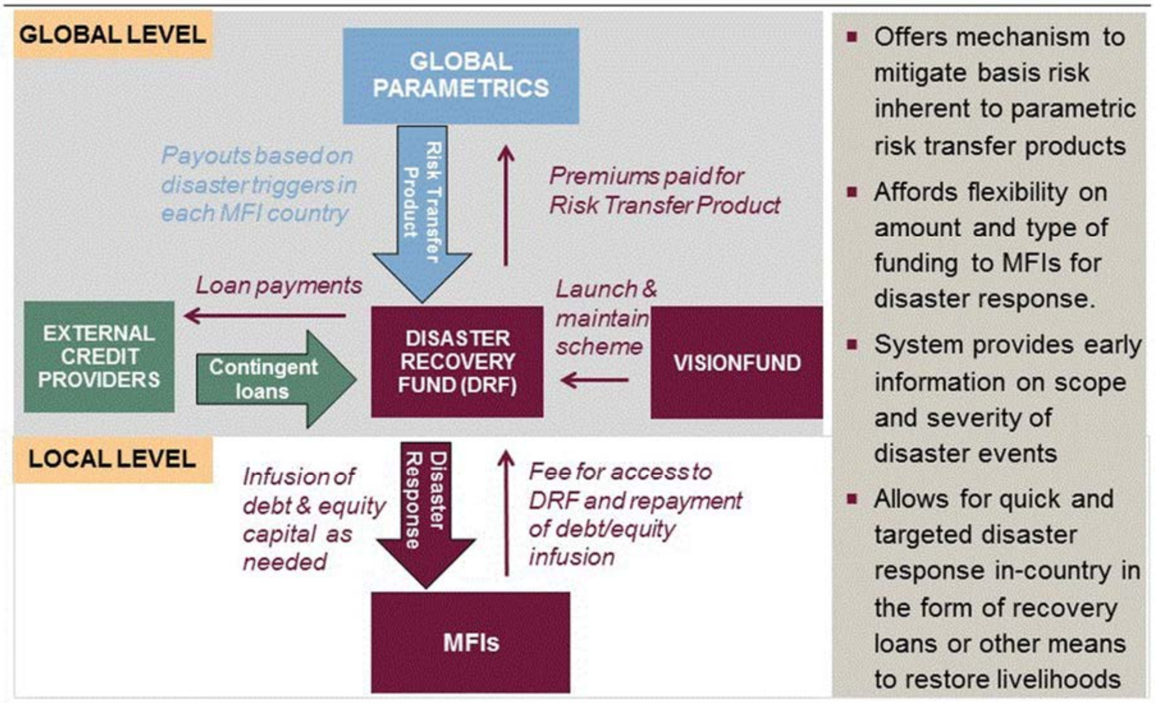

Figure 8.2. FDRM system design for MFI network.

The Local Level

The model assumes that the MFI capital needs will be met principally through the risk transfer product provided by a firm like Global Parametrics,[11] while additional liquidity needs will be met through credit provided by the DRF reserves, external liquidity providers and the MFI's local resources. The balance of credit and capital provision that the above terms produce, is illustrated by figure 8.3 below, which shows for one of the modeled network countries, the historical release of funds for credit needs (credit provision) and capital needs (covered by the risk transfer product). Note that for system implementation, the trigger thresholds will likely be reviewed and refined, with the potential for these to differ by geographic location to further optimize the system response.

The conditions under which different amounts of debt and equity capital will be released will be outlined in an agreement between the participating MFIs and the DRF. Template terms for the financial instruments within the system have been modeled as follows:

[11] The risk transfer product includes a deductible, and credit needs below this are assumed to be drawn from the DRF reserves.

MFI liquidity provision	MFI capital provision
Liquidity to support recovery lending makes up the majority of the financing provided through the DRF to MFIs, and is triggered for intermediate-level disasters with the following assumptions: **Trigger point** – hazard exceeding the 1-in-7 year return period[12,13] severity at the country level. **Limit** – 15% of the total country lending portfolio is taken as the maximum modeled credit need for recovery lending for any specific peril. This is the limit of credit provision under the mechanism. **Peril coverage** – excess rainfall, severe wind, and drought are modeled. **Payout function** – the model assumes that two thirds of the modeled credit needs are met through the DRF mechanism and the remaining one third is sourced by the MFI through local sources and existing liquidity.	The capital provision is triggered at a higher level of severity than the credit provision, and is limited to a third of the maximum liquidity provision. **Trigger point –** hazard exceeding the 1-in-10 year return period[14] severity at the country level. **Limit** – 5% of the total country lending portfolio is taken as the maximum modeled capital need for any specific peril. This is the limit of capital provision under the mechanism. **Peril coverage** – excess rainfall, severe wind, and drought are modeled. **Payout function –** as capital needs are being met through the risk transfer product, a step function is applied to the modeled credit needs to simplify credit provision. See the technical appendix for more details.

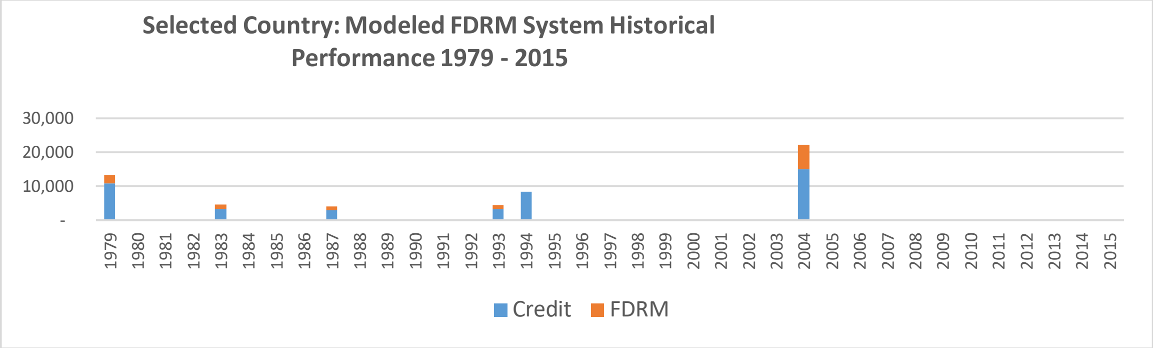

Figure 8.3 - Historical modeled performance of the FDRM system for a selected MFI country.

[12] Note that for extreme wind and rain contracts for both liquidity and capital offerings the country level return period has been approximated through the application of a franchise deductible, whereas drought contracts are set precisely to the specified return period.
[13] For Cambodia a 1-in-15 year return period severity was used for the trigger point for liquidity.
[14] For Cambodia a 1-in-25 year return period severity is used for the trigger point for capital.

The capital and credit balance

For moderate disasters, the system has been designed to respond first with credit for recovery lending, and then with capital once a higher level of hazard severity is breached. The capital and credit components are interconnected, as aside from repairing capital erosion for the more severe events, impacted MFIs will need additional capital to put them in a strong balance sheet position for the additional recovery lending planned. There are many scenarios under which it would not be possible to inject additional credit into an institution post-disaster, without first shoring up capital. Capital adequacy requirements under local regulatory regimes, but also from external liquidity providers, and from the DRF itself will influence this. Thus, to make external liquidity providers comfortable with the scheme, the ex-ante capital availability from the risk transfer product is important. The 1:3 ratio of limit for capital versus credit through the FDRM system is a preliminary view based on discussion with VFI, which will be refined for actual system implementation on a country-by-country basis.

MFIs pay a modeled average annual access fee as a percentage of their loan portfolios for the cover detailed above. This cost is set at a level to keep the overall system self-sustaining. As the size of VFI's portfolio and the corresponding FDRM program grows, it is expected that the DRF reserves will need to grow as well. It is currently envisioned that additional investments in DRF could be attracted from the participating MFIs and/or other outside sources.

The conditions under which capital and liquidity will be released under the final FDRM design may differ from the modeled terms above. Under the current model, live hazard data from Global Parametrics determines payouts to participating MFIs (risk transfer product triggers). This data will form part of the process ultimately used for contracting between the MFIs and the DRF, by providing a view of the severity and location of the disaster. However, the data may be combined with other decision-making processes – such as committee moderation, or other information sources - such that the mechanism for release of funds may not be purely parametric as currently modeled. The extent to which the release of financing under the agreement between MFIs and the DRF will be formally tied to the live hazard data, or to a committee decision, will be influenced by the final operating and ownership model of the DRF.

The Global Level

The portfolio of contingent liabilities arising from the MFIs subscribed to the FDRM solutions will be managed through the Disaster Recovery Fund (DRF). Any number of constructs and rules can be used to allocate the source of funds and the conditions for the flows. For example, in what is presented in this section, for events with return periods exceeding 7 years, 15 percent of the needed credit funding comes from the DRF and the remaining amount comes from a pre-arranged agreement with an outside provider of credit (e.g., a structure like what is presented in Section 6). The capital portion is trigger when there is a more extreme event (e.g., a 10 year return period or higher). The risk transfer product supports the capital by paying into the DRF for these events; in turn the MFN via the DRF passes the capital to the MFI.

Credit Provision

The credit needs arising from the agreements with MFIs to provide liquidity for recovery lending will be managed largely through ex-ante contingent loan agreements with external providers. A portion of the credit needs (currently modeled at 15%) will be met through the reserves of the DRF.

There are a number of entities that could provide external contingent credit facilities of the type required by the FDRM system model. In this context, contingent credit products involve fixing the terms and mechanism of lending before an event occurs. Users pay an annual access fee on the total amount of lending that would be made available under certain conditions through the facility. For the type of contracts that may exist between the DRF and the external contingent credit provider, a trigger drawdown that is structured similar to the risk transfer product that a firm like Global Parametrics may offer is envisioned. Using the same science for both the external call-down credit product and the risk transfer product would be important.

When it comes to the relationship between the MFN and the MFI, access to contingent credit can be more flexible. The information comes from two sources; 1) the science; and 2) the flow up from the MFI with regard to needs. Thus, the contingent credit draw down contract between the DRF and the MFI, can use the same science and with pre-specified needs. However, adjustments can be made either up or down depending on the flow of information coming up from the MFI. By doing this the DRF can serve as a buffer taking up some of the basis risk.

Capital Provision

The capital needs arising from the agreements between the DRF and the MFIs will be managed principally through the purchase of a risk transfer product. The terms of capital provision out of the DRF will be matched by the terms of risk transfer product such that the DRF is a conduit for these payments from the risk transfer product provider (e.g., Global Parametrics).

Additional Investments and Costs

As the MFI network's portfolio grows over time, it is assumed that the DRF reserves would need to grow in parallel. This additional investment could come from the MFIs themselves or other external investors. In order to attract this capital a modest return must be incorporated into the cost base of the DRF. The DRF will incur other costs in the course of its operations.

Performance Assessment

This section outlines the results for the FDRM system described above, when applied to the below portfolio (Table 8.1), on the basis of a 1,000-year simulation of disaster occurrence drawn from the Morrigu™ platform.

Table 8.1 - Modeled countries and limits for MFI network portfolio.

	Credit provision limits[15] (% of loan portfolio)			Capital provision limits (% of loan portfolio)		
Country	**Drought**	**Rain**	**Wind**	**Drought**	**Rain**	**Wind**
ECUADOR	10%	10%	0%	5%	5%	0%
HONDURAS	10%	10%	10%	5%	5%	5%
CAMBODIA	10%	10%	0%	5%	5%	0%
MYANMAR	10%	10%	10%	5%	5%	5%
PHILIPPINES	10%	10%	10%	5%	5%	5%
SRI LANKA	10%	10%	10%	5%	5%	5%
KENYA	10%	10%	0%	5%	5%	0%
MALAWI	10%	10%	0%	5%	5%	0%
TANZANIA	10%	10%	0%	5%	5%	0%
UGANDA	10%	10%	0%	5%	5%	0%
ZAMBIA	10%	10%	0%	5%	5%	0%

Referring to table 8.2, the model estimates a self-sustaining system meeting the credit and capital needs as defined above at an average annual cost of approximately 1.10%-1.25% of the total lending portfolio for participating MFIs. An approximate range is given as the ultimate cost will depend on the precise costs of managing and maintaining the DRF. The total estimated annual cost is made of three key components: the risk transfer product (~75% of the total), management expenses for staff and administration (~20%) and other operational expenses (~5%). As the program grows, management expenses are expected to benefit from economies of scale such that their percentage of the overall fee will go down as will the overall fee as a percent of the total portfolio. Changes to the underlying product structure and sum-insured levels would of course result in changes to the overall cost. In the scenario detailed here, there is $49mn of credit via the DRF mechanism, and $24mn of capital cover for the 11 countries listed. A $17mn contingent credit facility will need to be arranged with external providers to cover the modeled credit drawdowns through the DRF. With these figures, the balance of the DRF is maintained (at $3mn for the modeled portfolio at the outset) and allowed to grow in-line with the portfolio growth, and the DRF is able to meet its contingent credit and capital commitments to the growing MFIs. In comparison to the previous work done by GlobalAgRisk and VFI, the amount of additional liquidity needs from the DRF and external credit providers has

[15] The MFIs are assumed to be able to access credit totaling another 5% of their portfolio for the purpose of disaster response, bringing the maximum credit available for a disaster to 15% in total.

increased significantly. This reflects an evolution in the FDRM system design that now relies more on credit than risk transfer to fund the envisioned response to the MFI. In addition, the overall amount of the targeted response to extremes has been increased, which has driven the growth in the ex-ante funding needs.

Table 8.2. Key results for target FDRM system.

Key results	
Total credit provision limit	$49 million
Total risk transfer product sum insured	$24 million
Target balance of DRF	$3 million
External lines of credit to support credit needs	$17 million
Average annual MFI access fee (% of portfolio)	1.10%-1.25%

The role of the risk transfer product within the system was further examined by considering a 'captive' model alongside the above-modeled system, in which the DRF manages the capital outflows without the risk transfer product. Under these conditions, **a balance of $15 million for the DRF** is needed at the outset, to cover modeled capital outflows in addition to prior modeled commitments, and the resulting **access fee for MFIs is approximately 2.00% - 2.15%;** pushed higher by the costs of the DRF managing higher volatility of outflows.

System results for MFIs

The impact of the FDRM system can be best observed at the MFI level. Figure 8.4 below, shows the results of modeling for the FDRM system for a Cambodia portfolio. The model projects out 10 years to 2025, assuming a starting balance sheet position for the modeled institution, and using simulations from the Morrigu™ platform to model hypothetical event occurrence. In this model, we see the FDRM system supporting a higher growth trajectory for the Cambodia portfolio. This is due to an assumption that the MFI can leverage its capital base 25% more with the FDRM capital support in place. Note that significantly more market testing will be needed to refine this assumption on additional leverage. Also the additional growth is generated by the added credit provision for recovery lending, and risk transfer payouts mitigating the impact of two particularly severe years where capital erosion occurs.

For example, the significant deviations to the growth trajectory at 2021-2022 are a result of the modeled occurrence of a particularly severe disaster event in this year, which leads to significant long-term capital erosion for the institution. For this event, the FDRM credit mechanism responds with $11mn for recovery lending with an additional $6mn assumed to be sourced locally by the MFI, and the risk transfer product responds with a $3.9mn payout to repair the balance sheet erosion and support the recovery lending program. Consequently, the growth trajectory of the supported MFI is protected.

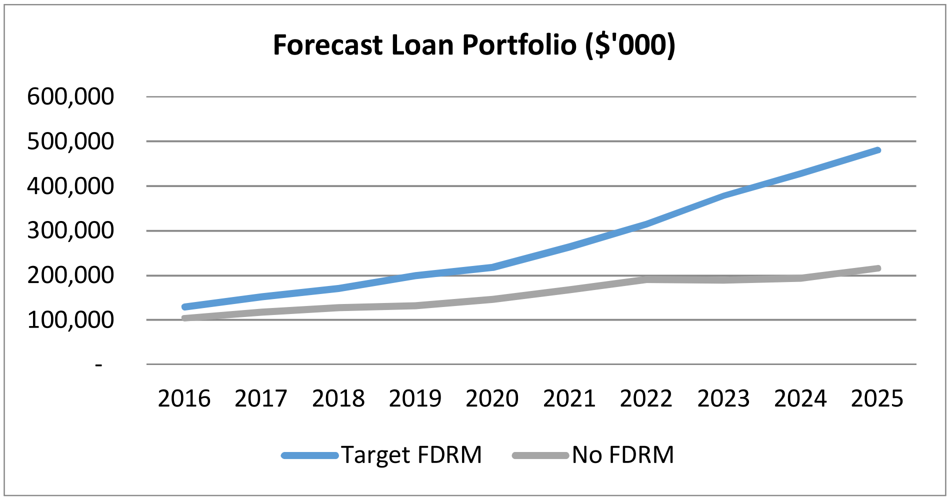

Figure 8.4 - Modeled growth under 10-year disaster experience for hypothetical Cambodian MFI portfolio.

The modeled results for Cambodia also show a major increase in the number of borrowers reached with recovery loans with the FDRM system in place (see Table).

Table 8.3 - Key results for target FDRM system for Cambodia.

Key results	With FDRM System	Without FDRM System
Average loan portfolio size over 10 years	$260 million	$155 million
Total borrowers reached with recovery loans	165,000	25,000

Section 9: Prototype Portfolio Disaster Risk Management for an MIV

BlueOrchard and GlobalAgRisk have together conceptualized a vehicle that offers emergency liquidity in the form of contingent credit, to MFIs exposed to disaster risk. The performance of this system has been modeled by GlobalAgRisk for a hypothetical portfolio of MFIs across the following countries:

Armenia, Ecuador, Georgia, Honduras, India, Kyrgyzstan, Malawi, Mongolia, Nigeria, Peru, Rwanda, Tajikistan

The model targets a mature portfolio of $130 million of emergency liquidity offerings for the vehicle, which is split equally as $5 million of cover for each country-peril combination. One hypothetical MFI is considered per country. This comprises exposure of $10 million for ten countries, across the perils of drought and excess rainfall, plus exposure of $15 million each for hypothetical MFIs in Honduras and India, where severe wind risk is also covered in addition to drought and excess rainfall.

The design of the vehicle and its emergency liquidity offerings are targeted to provide rapid contingent credit through ex-ante agreements with MFIs, and to underwrite and manage the resulting contingent liability from a large geographically diversified portfolio of subscribing MFIs. The vehicle takes the form of a fund under the management of a microfinance investment manager, such as BlueOrchard.

This section outlines the vehicle offerings and structure, how this is represented in the modeling, and what the modeling concludes with regard to the performance of the vehicle.

System Design Overview

Figure 9.1 shows the emergency liquidity offering (ELO) vehicle that takes the form of a fund. This fund offers disaster-contingent credit products to subscribing MFIs, and manages the resultant drawdowns of liquidity using pre-established credit lines, plus a risk transfer product (e.g. from Global Parametrics) for exposure beyond the capacity of these credit facilities.

MFI Level

The ELO fund will offer a pre-arranged credit facility for subscribing MFIs, up to a fixed limit. For our hypothetical portfolio, the MFIs subscribe for $5 million per peril, and per institution, in this case. For implementation, the limit of each MFI's credit facility will also vary depending on the strength of the MFI's balance sheet at inception of the agreement and how much cover they wish to put in place given their disaster exposure.

It is important to note that the strength of the MFI's balance sheet will not be static, and could in fact be highly impacted by the disaster itself that triggers the drawdown. If it is a regulated institution, deterioration of capital adequacy following a disaster (or even for some unrelated reason) may prevent the MFI from drawing from its pre-arranged ELO facility without resulting in a regulatory capital adequacy breach or breach of loan covenants. This has implications for product design – for example, the credit injection may need to be in the form of sub-debt rather than senior debt (as modeled), or it may be necessary to bundle the ELO product with a risk transfer product that injects equity under the scenario described. Products of the type described under Section 5 for the MFI network could play this role, providing a payout to shore up the capital position of the institution under particularly severe disaster conditions.

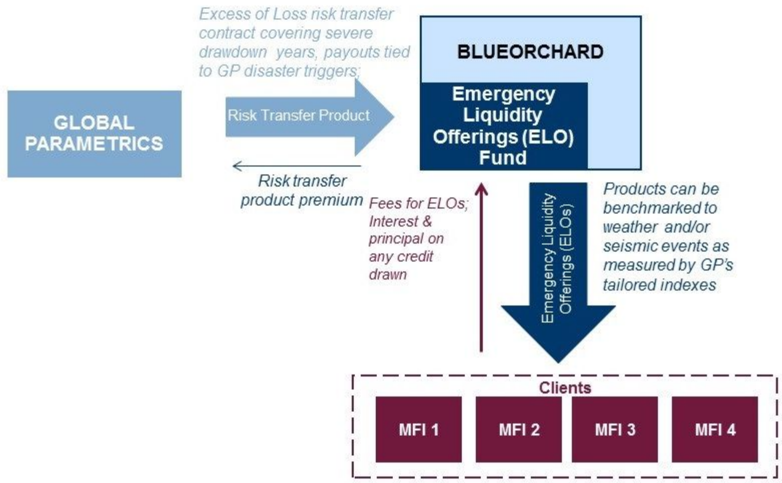

Figure 9.1 - Emergency liquidity offering (ELO) vehicle.

The conditions under which the MFI may draw down from the facility will be outlined in an agreement between the participating MFIs and the ELO fund. Parametric triggers may be used to determine qualifying conditions for drawdown by any MFI – for example, using the tailored disaster indices provided by Global Parametrics.[16] Alternatively, softer triggers giving more open access to the facility could be used, such as a self-declaration by MFIs of disaster occurrence.[17] A more open access trigger that gives more control to the MFIs around when they draw down from the facility poses some challenges in exposure management for the fund, as MFIs may drawdown for a broader range of event severities. It may therefore be preferable to use some parametric estimate of event severity as one of the determining factors in facility access post-disaster, if not the sole determining factor.

Under the current model, live hazard data from Global Parametrics determines when MFIs draw down from the fund (parametric risk transfer product triggers). A step function is used to determine the percentage of the facility that the MFI has access to, depending on different levels of disaster severity (see figure 5.2). The terms of the MFI-ELO are modeled as follows:

[16] The use of GP disaster triggers to determine contract drawdowns for the ELO products would result in a data service provider fee flowing between the fund and GP in addition to the cost of the risk transfer product.

[17] The precedent for such a system is the World Bank contingent credit offered to governments. Here, a national declaration of disaster is sufficient for full access to the loan facility. This type of open access tends to produce a higher frequency of drawdowns, which may not be preferable in the MFI context, where the facility should not be exhausted for small events, leaving the institution more exposed if an intermediate or severe level disaster should occur subsequently.

MFI emergency liquidity offering (ELO)

Trigger point – hazard exceeding 1-in-5 year return period[18] severity at the country level.

Limit – the limit of credit provision under the mechanism, and it will vary for each subscribing MFI for actual implementation. For the purposes of the model, $5 million for each institution, per peril, is assumed.

Peril coverage – excess rainfall, severe wind, and drought are modelled.

Payout function – the model applies a step function to credit drawdowns to simplify fund operations. This gives access to a different amount of the limit, depending on the severity of the disaster determined by the GP hazard indices (see right: **ELO step function for MFI access**).

ELO step function for MFI access

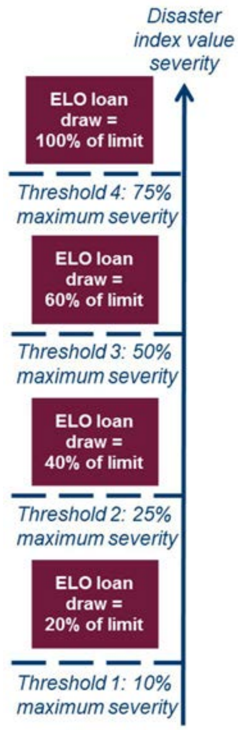

Figure 5.2 - Emergency liquidity offering access terms.

The model assumes that the MFIs draw 100% of the amount qualified for release for an event. It also assumes that any ELO products are drawn down as senior credit. Future analysis may also consider subordinated debt, convertible debt and equity offerings for the ELO product. A bundled offering to MFIs of an ELO product plus a capital infusion through a risk transfer product (see Section 5) could be considered, to assist MFIs with capital erosion that may arise from the more catastrophic disaster events, as described above.

Participating MFIs will pay an annual access fee to the fund, which is structured as a percentage of the total limit of their arranged contingent credit facility. This may be varied, depending on the risk exposure of the institution, such that a risk-based pricing scheme is applied. Alternatively, a fixed cost irrespective of the probability of drawdown could be used.

Fund Level

The above described agreements with MFIs result in annual aggregate contingent liability of $130 million of emergency liquidity for the fund. To manage potential outflows from this aggregate total, the vehicle uses pre-established dedicated liquidity and a risk transfer product structured as an excess-of-loss (XoL) contract. The model assumes that dedicated liquidity of $20 million is available to the fund through credit lines, and that drawdowns exceeding this are

[18] Note that for extreme wind and rain contracts for both liquidity and capital offerings the country level return period has been approximated through the application of a franchise deductible, whereas drought contracts are set precisely to the specified return period

covered by the risk transfer product, up to a limit, as depicted in Figure 9.3. This limit for the XoL risk transfer product is equal to the probable maximum drawdown (minus the credit line capacity) plus a 10% buffer, for the modeled hypothetical portfolio.[19]

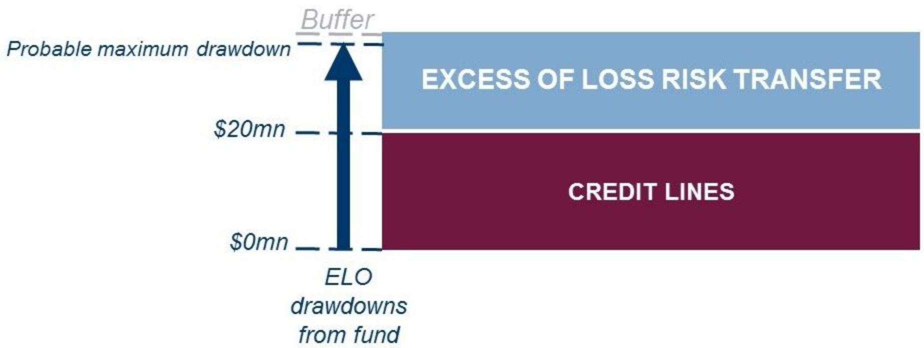

Figure 9.3 - Modeled drawdown exposure management for the ELO fund.

Performance Assessment

This section gives an overview of the results for the ELO fund described above, for the hypothetical portfolio of MFIs modeled as a mature portfolio scenario for the fund, given in table 9.1. The analysis uses a 1,000-year simulation of disaster occurrence drawn from the Morrigu™ platform. Thirty-seven years of historical modeled hazard occurrence are also used to model a hypothetical evolution of the fund, starting at inception with limited MFI subscription.

[19] The use of the modelled PML plus a 10% buffer to determine cover requirements is presented as an example, and does not constitute financial advice. The fund manager may opt to use a different strategy for catastrophe exposure management.

Table 9.1 - Modeled countries and limits for hypothetical MFI portfolio under ELO fund.

	ELO facility limits under mature portfolio scenario		
MFI Country	**Drought**	**Rain**	**Wind**
ARMENIA	$5mn	$5mn	
ECUADOR	$5mn	$5mn	
GEORGIA	$5mn	$5mn	
HONDURAS	$5mn	$5mn	$5mn
INDIA	$5mn	$5mn	$5mn
KYRGYZSTAN	$5mn	$5mn	
MALAWI	$5mn	$5mn	
MONGOLIA	$5mn	$5mn	
NIGERIA	$5mn	$5mn	
PERU	$5mn	$5mn	
RWANDA	$5mn	$5mn	
TAJIKISTAN	$5mn	$5mn	

Due to geographic diversification, the total aggregate exposure to ELO agreements of $130 million produces a modeled maximum annual drawdown of $37 million for the fund. Assuming the $20 million dedicated liquidity capacity for the fund, and a 10% buffer on top of the probable maximum drawdown, this means that the fund would need to purchase an excess of loss risk transfer product valued at $19 million. Key results are presented in table 9.2.

Table 9.2 - Key results for modeled ELO fund.

Key results	
Total emergency liquidity offerings under mature portfolio scenario	$130 million
Excess-of-loss risk transfer product sum insured under mature portfolio	$19 million
Excess-of-loss risk transfer product cost as a % of total ELO portfolio	0.8%
Probable maximum annual drawdown from ELO facility	$37 million
Probable maximum annual risk transfer product payout	$17 million

Cost Assumptions

Further product development is required to converge upon cost assumptions. These will depend on factors such as:

- The nature of the ELO triggers (e.g. for parametric triggers the cost of live hazard data from Global Parametrics or a similar provider needs to be factored in. For other types of triggers, the modeled probability of drawdown would need to be adjusted to reflect more open access, and higher uncertainty in the modeled drawdown figures);
- The cost of dedicated liquidity to the fund, which will depend on the fund operating details to be determined during implementation;
- Interest revenue on the ELO loans, which will vary by territory and MFI;
- The performance of the ELO loan book.

Using some placeholder assumptions that will alter significantly for a real portfolio of subscribing MFIs, GlobalAgRisk modeled some sample results, using the historical time-series of modeled hazard data from 1979-2015 and assuming a portfolio of $52 million at fund inception, growing 12% per year. The model assumed that $20 million of dedicated liquidity was available from the outset, and that the fund purchased increasing amounts of excess-of-loss risk transfer product to supplement this as drawdowns increased with the growing portfolio.

The results showed that the fund generated an average annual return on assets of between 1.5% and 3.5% depending on the costs of supporting ELO products and the amount that can be charged to MFI clients for access to the products.

Section 10: Benefits of Pooling Risk

It has been extensively demonstrated in the field of disaster risk financing that individual entities gain significant benefits from pooling their risk, and accessing contingent financial instruments on a combined basis. There are a growing number of examples of successful risk pooling schemes – such as the Caribbean Catastrophe Risk Insurance Facility, the Pacific Disaster Insurance Pilot, and the African Risk Capacity facility where countries take a collective approach to accessing disaster risk insurance. More generally, the principle of pooling risks into a diversified portfolio is the fundamental basis on which the insurance industry has operated successfully for hundreds of years.

Risk pooling lowers the cost of contingent financing, such as contingent credit or insurance-like risk transfer products. There are two principle ways in which this occurs: through the sharing of fixed costs across a larger group of insureds; and through the fact that a smaller 'backstop' of capital or credit to deal with large losses is needed for the group per unit of portfolio coverage, due to diversification of loss occurrence. This lower cost of capital[20] feeds into the cost of contingent financing.

To demonstrate this effect, GlobalAgRisk has simulated the combination of the modeled VFI portfolio as presented in Section 5 with a synthetic portfolio created for a hypothetical MFI network (see Table 10.1). A large synthetic loan portfolio around 40% larger than the VFI modeled portfolio is used, and with a very different geographic profile, overlapping only in two of eleven countries modeled for VFI: *Armenia, Ecuador, Georgia, Honduras, India, Kyrgyzstan, Malawi, Mongolia, Nigeria, Peru, Rwanda*.

Table 10.1 shows **a 31 percent reduction** in the maximum credit response funding need through the FDRM system, when the two modeled MFI networks pool their risk. This translates into a smaller contingent credit facility to be arranged with external liquidity providers and if the risk transfer product cover can be pooled as well the limit for the risk transfer product might be reduced (see Figure 8.2. FDRM system design for MFI network.). Therefore, in the context of the FDRM system, the annual access fee for the contingent credit facility and possibly the cost for the risk transfer product could be reduced.

[20] Or credit, where a contingent financing mechanism is backed by a contingent credit line.

Table 10.1 - Benefits of pooling risk for two modeled MFI networks.

MAXIMUM CREDIT RESPONSE FUNDING NEED (capital needs assumed to be met separately by a risk transfer product)		
VFI modelled portfolio	$	20 million
Synthetic network portfolio	$	23 million
Total (for independent operations)	$	43 million
Combined portfolio	$	30 million
Reduction in funding need	$	13 million
Percentage reduction of total maximum funding need		31%

While these results are consistent with classic pooling effects obtained when bringing different and largely uncorrelated asset classes into an investment portfolio, it is useful to visualize how these results are obtained when pooling risk transfer products across countries. Figure 10.1 provides this visualization via the dynamics of pooling risk in practice using the example detailed above. The three graphics show the modeled historical credit response needs for the synthetic portfolio, VFI portfolio and combined portfolios. As can be seen in these three examples, the stand alone maximum response need is $23 million for the synthetic portfolio which occurs in 1996 and $20 million for the VFI portfolio which occurs in 2004. However, when the portfolios are combined rather than simply adding the two maximum responses to get $43mn in total need, one can see that the maximum combined event occurs in 1994 and only reaches $30mn across the two portfolios, evidencing the notable benefits of pooling risks.

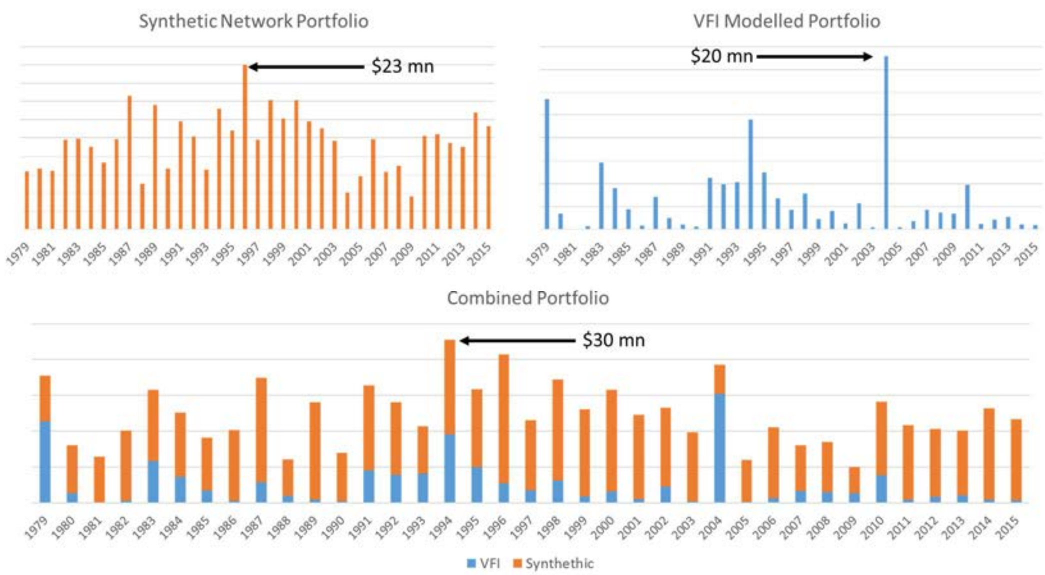

Figure 10.1 - Graphical representation of the benefits of pooling risk.

Section 11: Implementation and Legal-Regulatory Considerations

Post-disaster recovery lending and liquidity injection programs to affected MFIs and populations require there to be in place a delivery infrastructure, information systems for both design and response, and availability of funds if the effort is to be timely and effective. A successful implementation requires a planning process that focuses on two jointly dependent components for MFIs that drive the ability of a microfinance network owner or investor to achieve intended outcomes:

- Financial capacity
- Operational capacity

Building both of these capacities is critical to step 2 in the ex-ante financing process. Financial capacity refers to the ability to *quickly* mobilize additional funds (capital and/or liquidity) to respond to a disaster triggered by natural hazards. Given that an MFI, when operating efficiently, may be fully leveraged in assets and margins, effecting an on-demand surge in resources following a natural disaster is a non-trivial problem. Along with a jump in demand post-disaster for financing, the MFI will likely face a disruption in operational activity and corresponding increase in operational expenses. This is the strength of the FDRM system as an ex ante financing mechanism: the ability to rapidly release funds in proportion to the event. In addition to surge resources, financial capacity also represents the ongoing costs that must be covered, primarily for the risk transfer services and liquidity access, but also the additional costs in preparing for and executing the assessment and lending/liquidity process.

Operational capacity refers to having on-site following a disaster event the human capital resources who have the ability to manage, who are empowered to make decisions and take action, and who understand the goals and objectives of the recovery lending and liquidity programs. As with financial capacity, an individual MFI may be highly leveraged in personnel such that it becomes difficult to implement disaster contingent initiatives. While Operational capacity is enhanced when the implementation process is codified, set procedures will only go so far, and in a dynamic environment it will become necessary to observe and adapt to opportunities as the situations evolve. Part of the necessary skill set includes an understanding and ability to manage the legal and regulatory environment that disciplines the flow of funds into a country and between institutions, as well as their permitted use.

An implementation plan that achieves these capacities can take different forms depending on the objectives and structure of the particular institution. For instance, it is unlikely that a microfinance investor will have a fully aligned disaster response strategy with its borrowers, whereas a microfinance network owner may be able to play a more active role both in planning and post disaster response. The degree to which that takes place will depend on the particular institution, and that which follows should be viewed as a starting point for discussion and decision points regarding individual and shared responsibilities.

The following is an example of a four-part implementation plan of a microfinance network owner that wishes to ensure that its network members are able to endure the financial consequences of a natural disaster and be capable of initiating a recovery lending program for its customers and other members of the impacted communities. The framework, while pointing to the various analysis highlighted previously in this paper as examples, encompasses a broader set of elements. It is followed by an outline of an implementation plan for a microfinance investment manager who is seeking to provide an emergency liquidity facility to microfinance institutions looking to proactively manage their financial response to disasters.

Network Owner Implementation Framework

The following four-part implementation plan lays out a full set of design and capacity building activities for a network owner spanning multiple countries.

Step 1: Weather, Agricultural Science, and Risk

An early component involves ongoing risk assessment over the geographies served by each of the network MFIs. Weather data from the Morrigu™ platform is brought together with GIS services to map drought, excess precipitation, and windstorm in order to gain a view of severity and frequency of events. Agricultural exposure to weather risk also needs to be understood in terms of the local experience with past disaster events and portfolio impact and the seasonality of agricultural systems and their vulnerability as it relates to the agricultural lending portfolio. Non-agricultural loan product types should also be risk assessed either as directly impacted (typhoon) or secondary effects (food price increases putting pressure on household finances). All of this assessment feeds into developing a provisional range of meaningful threshold return period levels to be used in the financing mechanisms of the FDRM system.

Step 2: End-to-End Financing Solutions

The conceptual view of the FDRM system for a microfinance network owner is made concrete through financial modeling of the MFI's portfolio exposure to natural catastrophe, supported by iterative local input to associate potential event severity with exposure and impact. In particular, an assessment and agreement must be made of the anticipated liquidity and capital needs over a variety of likely future events that ensures both institutional survival and supports an active recovery-lending program. Both items must be informed by current and anticipated capital allocation, balance sheet leverage, and accounting rules that are likely to vary between institutions and jurisdictions. Once the overall magnitudes and balance between liquidity and capital is agreed in relationship to risk and exposure, the risk transfer product provider can provisionally price the risk transfer component, as well as sizing the appropriate contingent liquidity pool, for both the individual MFI as well as the pooled network.

Step 3: Information, Capacity and Funds Management

The microfinance network owner must establish a coordinating system and expertise to manage the various aspects of an active and dynamic global FDRM system, as envisioned in the figure 8.2 presented in Section 8, and to support locally implemented recovery lending.

Chief among the tasks of the coordinating system is the management of funds flows across the overall network. These include for instance the management of fees from subscribing network MFIs to support the global risk transfer product premium as well as funds flowing back to MFIs from triggered FDRM payments. Other responsibilities include the holding and management of the central pool of buffer funds and liquidity lines of credit tied to the FDRM system. Critical to achieving these functions is having the specialized skills to develop appropriate processes for efficiently and rapidly moving funds to and from each of the network members considering the implications of foreign exchange, tax and regulatory obligations and other transfer issues that will affect the movement of funds among entities. The network owner can bring this capacity on behalf of the network members through the structure of the coordinated system.

The network owner will also have other capacity and resource advantages over individual network members. For instance, the network owner will likely have a broader base of experience in specifying and negotiating the design of risk transfer products as well as having a stronger bargaining position when negotiating product pricing. Finally, the network owner can also act as a central clearinghouse for other support and information services related to the FDRM system as well as its integration into unified business and contingency planning.

Step 4: Qualification and Recovery Support to MFIs

The three previous steps in the implementation are primarily directed toward supporting an MFI's surviving a deterioration of its portfolio following a disaster and to provide the resources to facilitate a recovery lending activity to help rebuild clients and communities. Much of this has focused on financial and coordination activities operating at the 'global' level. This last component directs recovery lending advisory services and performance knowledge discovery at the MFI level. However, there may be cases where it is more cost efficient to centrally provide a variety of specialized services.

Pre-disaster support includes a standardized qualification assessment for admission into the FDRM scheme, which includes assessment for capacity to effect recovery lending. Some MFIs may need to review and act to improve fundamental business practices before they are able to fully appreciate and capture the benefits of adopting the disaster risk management system. Pre-qualification is a feature of most emergency liquidity facilities for financial institutions. The FDRM system provides both liquidity and capital so similar standards in areas of financial reporting and performance, staff education, and pre-planning are likely to be implemented over a reasonable time-frame.

Part of the planning support includes advice on the types of product models and methods that could be used during recovery lending following a disaster. Its key here to remember that 'recovery lending' as broadly used can include a variety of adjustments to outstanding loan obligations as well as the facilitation of new lending, but both must be developed in light of local custom, staffing capacity, and scenarios of financial performance while the MFI is under stress. Models for new lending for significant disaster recovery can be informed by global examples, but must be tailored to local experience with past disaster events and client's needs. Estimates of demands and loan types combined with knowledge of an MFI's capital allocation will help refine the risk transfer products themselves.

Post disaster, an MFI will likely benefit from consultancy services for the recovery lending effort, using specialists who have prior experience in adapting to different and rapidly changing circumstances, who are connected with key members of the NGO disaster relief community, who are knowledgeable about how to interface with these resources on behalf of clients. In addition, post-disaster services can include legal, regulatory, and financial help in navigating the rules around international funds movements, negotiating with wholesale lenders, and advocacy for special regulatory dispensation. Using specialists in this manner should not be viewed as substituting for pre-planning or a criticism of local staff capacity. It does recognize, however, that natural disaster management requires an adaptive management mindset where not every contingency can be anticipated, and that local staff at every level will be already working at capacity.

The final component of MFI support involves the monitoring and evaluation of the FDRM system and recovery lending effort. This too requires pre-planning to put in place the kinds of MFI and client level financial, wellbeing and other relevant indicators that are needed to attribute the intervention to specific hypothesized outcomes, such as those outlined in the theory of change in the first section. Monitoring and evaluation should not be considered an academic curiosity, but rather the means to building long-term evidence of whether the intervention, the FDRM system and recovery lending, lead to the intended outcomes, if the outcomes are being efficiently provided, and if the system can be adapted elsewhere.

Natural disaster recovery and contingent financial interventions such as FDRM are difficult to rigorously evaluate due to problems with identifying a suitable counterfactual. One reason is because disaster arrival and geography is generally unknown in advance making proper design and pre-disaster benchmarking difficult. Nonetheless, disaster events sometimes present unexpected 'natural experiments', and other methods have evolved to provide for reasonable validity when there is an opportunity to gather the required information (see, for example, Becchetti and Castriota 2011). While monitoring and evaluation can be much more modest than required for strict academic acceptance, even efforts that focus solely on MFI performance outcomes may require additional reporting needs over a multi-year time horizon and careful interpretation, skills better provided through support from specialists in the field of monitoring and evaluation.

ELO Fund Operated by Microfinance Investment Manager

This section proposes an outline for an implementation plan for a microfinance investment manager seeking to provide an emergency liquidity facility to microfinance institutions. This concept is detailed in Section 9 above. Items that have been identified at this stage with respect to active implementation are as follows:

Demonstrating Value Added to MFIs – Proof of Concept

The first step for implementation is to assess and build demand for the emergency liquidity offering (ELO), by providing a proof of concept. Recovery lending is an innovative concept and in some respects counterintuitive: when disasters strike, the first response for most lenders is to retrench and limit risk exposures, therefore reducing, rather than augmenting, both borrowing and lending to preserve capital. As such, it would be important to demonstrate to MFIs that recovery lending is a concept that would provide a valuable service to their end-clients, helping them to rebuild their businesses and their livelihoods following a disaster, while not jeopardizing the financial sustainability of the organization. The role of recovery lending in protecting the growth trajectory of MFI portfolios, as demonstrated in Section 3, would also need to be emphasized and demonstrated to potential users of the ELO product. As such, a pilot program to demonstrate successful implementation of this concept could be used to provide evidence to MFIs of the value added of this proposition in order to obtain buy-in and participation in the ELO facility. Demonstration of proof of concept could therefore comprise:

- Roll out of a pilot scheme for an emergency liquidity offering to a limited number of interested MFIs and countries;
- Dissemination of the results of this pilot, and also of the results of recovery lending work already undertaken or ongoing by VFI and others in the Philippines (post the 2013 Typhoon Haiyan), Ecuador (following the earthquake in April 2016) and in East Africa following the severe weather conditions produced by El Nino (2014–2015).

The results of such recovery lending projects would provide important information to prospective MFI users of an ELO product potentially managed by a microfinance investment manager. A second stage to the proof of concept could be to expand the pilot to additional microfinance network owners (again, some potential partners for this have been identified) before creating a facility that would be available to a broader range of MFIs, beyond the network collaborations for the pilots.

A Phased Approach to Fund Launch

Establishing a stand-alone ELO fund, with sufficient investors and investees would likely be challenging at the early stage, and therefore a sequenced approach could be applied, whereby an ELO Fund would initially begin as a sub-compartment of an existing fund structure. As the pilot programs progressed, and demand for the ELO product became established at a viable level, a dedicated ELO fund structure could be established.

Addressing Potential Borrower Capital Constraints in Product Design

Depending on the magnitude of an MFI's exposure to a region impacted by a natural disaster, such a disaster that would trigger an ELO disbursement to an MFI could have significant near-term impacts on that MFI's profitability and capital levels. In such cases, providing additional lending to the institution through an emergency liquidity offering facility could result in a breach of regulatory capital requirements and/or loan covenants with the lender.

This needs to be considered when determining the conditions under which an MFI could draw on the ELO facility, and the type of debt (sub-debt for example, versus senior debt, in order to be eligible as Tier II equity) to be provided. Again, experiences of VFI and others in recovery lending could help inform how the product is designed for active implementation. As detailed in Sections 8 and 9 above, pairing the emergency liquidity offering with an equity injection could be one option examined. A risk transfer product of the type described under Section 7 for the MFI network could play this role, providing a payout to shore up the capital position of the institution under particularly severe disaster conditions.

Additional Technical Work to Reconcile Accounting Issues of the Fund

The current concept for an ELO fund considers the use of a risk transfer product to manage large draw-downs from the facility, beyond the capacity of existing credit line arrangements. In the event that an FDRM payment would be triggered, the ELO fund would receive a cash payout that would then be only on-lent, but not paid out, to the beneficiary MFIs. This would need to be carefully considered such that it is appropriately accounted for at the fund level. This is particularly important for open-end fund structures (such as the BlueOrchard Microfinance Fund) that require regular mark-to-market valuations and provide regular liquidity for investors to enter or leave the fund at such valuations. Provisions could be taken to offset the payouts (with the rationale that the ELO loans made would carry a higher risk) in order to neutralize the impact of the payout on the fund net asset value, and provisions would be released over time, as appropriate, depending on the performance of the ELO loans. Such matters would, however, need to be vetted in additional detail with appropriate accounting and fund administration experts as part of implementation.

Legal and Regulatory Considerations

Portfolio Disaster Risk Management for an MFN

The FDRM system outlined in this Report envisages the establishment by an MFN of a Disaster Recovery Fund (DRF) that would be used to provide participating MFIs affected by a natural disaster with liquidity funding and, in the case of a more catastrophic disaster event, an infusion of additional capital. The DRF will use its own reserves, contingent loans and a FDRM contract with embedded risk transfer products with a provider such as Global Parametrics to fund the additional liquidity and capital. To implement the proposed FDRM system, it will be necessary to develop contracts governing the relationships between the various parties.

Given the wide range of countries in which impacted MFIs are located, and their differing circumstances, it is not possible to develop a prototype set of contracts in this Report, or even to provide detailed and specific guidance. The contracts appropriate for an MFN and its network MFIs will need to be developed on a case-by-case basis. The purpose of this Section, therefore, is to consider some of the legal and regulatory issues that should be considered in developing the contracts and that may have an impact on the implementation of the envisaged FDRM system, to provide general guidance and to discuss some of the options that may be available. Given the wide range of potential jurisdictions and circumstances, at both the global and local level, this Report does not contain any specific jurisdictional legal and regulatory analysis.

Outline Contractual Framework

Section 8 envisages that, at the global level, the contractual framework will comprise:

- Contingent loan agreements with external credit providers that, together with reserves held in the DRF, will fund liquidity payments to affected MFIs; and
- A risk transfer contract with a provider such as Global Parametrics that will fund the infusion of capital.

Liquidity will be provided to MFIs through loans, which will be governed by loan agreements entered into with each MFI. An infusion of capital may take a number of different forms, not all of which of which would need to be governed by a contract with the MFI, as discussed further below.

Although the purpose of the global level contracts is to provide the funds necessary to finance the liquidity payments and the capital infusions to be provided from the DRF, there is no need to combine the global and local level contracts into a single contract, and to do would be likely to add significant legal and regulatory complications. In the circumstances, it is envisaged that the FDRM system would require separate contracts between the MFN and/or the DRF with:

- Each external credit provider;
- One or more risk transfer providers, such as Global Parametrics; and

- Each participating MFI.

The DRF

The DRF plays a central role in the envisioned FDRM system. A decision on how the DRF is to be established and constituted is therefore a critical first step in the design of a FDRM system for an MFN. The possibilities include the following:

1. The DRF could be established as a separate entity or with legal personality (for example limited partnerships in some jurisdictions have legal personality, but are not corporate bodies). This would most likely take the form of some type of profit or not for profit company or corporation, depending on the corporate vehicles available, and the consequent tax implications, in the jurisdiction in which the DRF is to be located. As a separate corporate body (or as a fund with legal personality), the DRF would have the capacity to hold assets and to contract. The DRF would therefore be able to enter into contracts at both the global and local levels in its own right.
2. The DRF could be established as a segregated pool of assets managed by the MFN. In this case, the DRF would not be able to enter into contracts in its own right, whether at the global level or with MFIs, and would not be able to hold assets. The contracting party would almost certainly be the MFN and the DRF assets would be the property of the MFN.
3. The DRF could be established as a trust fund. In this case, the assets would be held by trustees and the trustees would enter into contracts in relation to the DRF. The trustees would be required to deal with the assets in accordance with the terms of the trust instrument. This may be an attractive option if the DRF is funded, in whole or in part, by third party funding agencies.

There are other options, such as establishing the DRF as a foundation or as a fund managed by an external fund manager as envisioned with regard to the ELO (see the earlier discussion in this Section concerning the implementation of the ELO).

The decision on whether to establish the DRF as a separate entity will most likely depend principally on a number of practical considerations, such as the size of the fund, the costs of establishing the fund as a separate entity and how the fund is to be managed. If the DRF is to be established by multiple MFNs, it would be much easier to manage the DRF if it was to be established as a separate legal entity.

If the DRF is not established as a separate legal entity or as a formal trust, consideration may need to be given as to whether to protect or ring-fence the funds so that they are not intermingled with other assets of the MFN. Although this may not strictly be necessary, it may increase the confidence of the participating MFIs and any third-party funders.

It is unlikely that there would be a regulatory impact on the DRF if established by a single MFN. However, if the DRF was to be jointly established by more than one MFN, there is a risk that the fund would be subject to regulation as a collective investment scheme, or equivalent. This would need further consideration taking into account the investment and funds legislation of the jurisdiction in which the DRF is to be located.

Global Level Contracts

As discussed in Section 8, it is envisaged that the contingent loan agreements entered into by the DRF with external credit providers would give the DRF the right to draw down on the credit line on the basis of triggers structured similarly to those in the risk transfer product that would be offered by a firm such as Global Parametrics.

Although the envisioned index-based triggers are not typical, the concept of a contingent loan agreement is not unusual and would not normally be subject to any form of regulatory control. If the contingent loan agreements do not also include hedges to cover other risks, such as currency or interest rate risk, it seems unlikely that the index-based triggers in themselves would cause the contingent loan agreement to be considered as a derivative or to be subject to any form of regulation.

As indicated, the parametric-based risk transfer product has been designed to have many of the features of an insurance contract. Although it is likely to be sold as a derivative, there is a risk that the contract would be regarded by a regulator as an insurance product. If so, the product could be offered only by a firm such as Global Parametrics if authorized as an insurer. Given the extent to which derivatives are used for hedging risk in mature jurisdictions, this is unlikely.

It is envisioned that the global risk transfer product would be sold as an “over-the-counter” or “OTC” derivative, i.e. a derivative that is not tradable on an exchange. It is expected that parametric-based OTC derivatives would be a major part of the product offering of a firm such as Global Parametrics. It will, therefore, already have assessed the extent to which, as a provider, it is subject to regulatory control (if at all) and, if required to do so, it would have obtained the necessary authorizations before participating in the FDRM system. In the circumstances, it is not necessary to consider the regulatory status of a firm such as Global Parametrics in this Report.

However, whatever the regulatory position of Global Parametrics, or a similar provider, it is considered extremely unlikely that the DRF, as a non-regulated end-user of an OTC, would be impacted by any additional regulatory requirements or obligations.

Local Level Contracts

Legal and regulatory complications are more likely with the local level contracts between the DRF and the participating MFIs, and these could be significant. Although there are likely to be very few global level contracts and possibly just the legal and regulatory framework of one jurisdiction to consider, at the global level, each MFI participating in the FDRM system is likely to be in a different jurisdiction, each jurisdiction will have its own legal and regulatory framework and the various participating MFIs are likely to be differently constituted with different ownership structures and to have differing regulatory authorizations.

To illustrate the problem, VFI has MFIs in 32 different jurisdictions with a mixture of common law and civil law legal systems. Each country has its own legislation, regulatory requirements and financial services regulator. To complicate the position further, some of the MFIs are constituted as ordinary companies, some as LLCs and some are foundations. With respect to regulatory status, some of the MFIs are unregulated non-bank financial institutions (NBFIs), some are regulated (non-deposit taking) NBFIs and some are regulated as non-bank deposit taking financial institutions. Finally, there are different ownership structures. Some of the MFIs are wholly owned by VFI, VFI is a majority or minority owner of others and some (particularly the NGOs) do not have a conventional ownership structure.

With so many permutations, separate local level contracts will need to be developed for each MFI. It is likely that other MFNs will have different arrangements.

The first step in implementing the FDRM system at the local level will be to undertake a scoping exercise to identify the key issues in respect of each MFI. The scoping exercise should be designed to answer at least the following questions:

1. How is the MFI constituted, e.g. as a company, LLC, foundation, cooperative or other entity?
2. What is the ownership structure, i.e. does the MFI issue shares or their equivalent and who are the holders of the shares? If the MFI does not have a conventional share structure, is it constituted as an entity without owners, e.g. a company limited by guarantee.
3. What is the organizational structure, e.g. a board of directors, governing council etc. and who would need to approve the local level contract?
4. What is the legal system in the country in which the MFI is based and is there codified contract law?
5. Is the MFI regulated? If so:
    a. Is the MFI subject to prudential regulation, i.e. is it regulated with respect to its capital and financial condition (which will almost certainly include the control of key financial risks)?
    b. Is the MFI regulated with respect to business conduct?
6. Who are the regulatory and supervisory authorities for prudential and conduct regulation? There may be a number of authorities with different responsibilities. For example, the regulatory authority may be different to the supervisory authority).
7. Whether each proposed contractual arrangement will be subject to any type of regulatory control and supervision and, if so, whether the contract can only be offered by a regulated entity.

Provision of Liquidity

It is useful to examine the objectives of the FDRM system at a local level in a little more detail. As indicated in Section 8, it is intended that the liquidity provided to an MFI should take the form of a contingent loan. However, unlike the global contingent loan agreement, there may be a mix of hard parametric triggers and softer triggers designed to manage basis risk.

Once a loan is triggered it will need to be repaid. Although conditional loan agreements may not be common in some developing and emerging market countries, it is unlikely that the contracts themselves would attract regulatory attention.

However, if an MFI has been severely affected by a natural disaster, it is possible that its ability to incur additional liabilities could be constrained. For example, if the MFI is subject to prudential regulation, it is possible that the regulator would require an MFI to be recapitalized before it incurs additional liabilities, particularly if the funds borrowed by the MFI will be on-lent to clients as this would further dilute the MFI's capital ratio. Insolvency legislation may also constrain the ability of an MFI, whether regulated or not, to incur liabilities if it is close to insolvency.

It may be possible to mitigate or even circumvent these problems if the MFN were to agree that its claim to repayment is subordinated to the claims of other creditors. Alternatively, the MFN could agree that the MFI's obligation to repay part or the whole of the loan is itself conditional on certain conditions intended to postpone the obligation to repay until the financial condition of the MFI has improved. It would be important to ensure that the repayment conditions are objective and readily measurable. For example, the obligation to repay could be linked to the MFI's capital ratio.

Subject to the regulatory considerations outlined, it is unlikely that a conditional loan agreement, even with parametric triggers, would cause significant problems.

Provision of Capital

The provision of capital is rather more complex. The objective of a capital infusion is that the MFI should receive additional funds that will strengthen its balance sheet. It is not intended that the MFI will be required to repay the funds provided to it as capital.

If the MFI is not subject to prudential regulation, any mechanism that achieves this objective could be considered. However, if the MFI is subject to prudential regulation, there will be a definition of capital for regulatory purposes and, if the MFI's capital has fallen below the required minimum, it will be necessary to ensure that the capital infusion is in a form recognized as regulatory capital.

Consider first the case of a non-regulated MFI. An increase in the assets of an MFI without the creation of a matching liability must have the effect of strengthening the MFI's balance sheet. Without the need to consider regulatory requirements, an MFN could simply transfer the proceeds, or part of the proceeds, of any payout made under its risk transfer agreement with Global Parametrics or a similar firm to the MFI as a voluntary payment, outside any contractual arrangement.

However, this approach is not compatible with the envisioned FDRM system. First, the FDRM system is designed to provide an ex-ante financing approach, but a capital infusion made after the event at the discretion of the MFN does not provide an MFI with the required level of certainty to be able to plan for the natural disaster. Second, it is intended that MFIs should pay a participation fee. It seems unlikely that an MFI would be prepared to do so without a clear agreement from the MFN to provide a capital infusion if a natural disaster should occur.

If there is no requirement to satisfy a regulatory capital requirement, an agreement could be entered between the DRF and the MFI to provide a cash payment on the triggering of an index. This would mirror the global level agreement with Global Parametrics or a similar firm. Whilst, in a mature jurisdiction with sophisticated counterparties, this would be regarded as a derivative, it is far from clear that this would be the case at the local level.

As previously indicated, the global contract has been defined using insurance principles to provide insurance-like cover and benefits. In a jurisdiction with a less sophisticated legal and regulatory framework, there is a significant risk that the contract would either fall within the legal definition of an insurance contract, or would be classified as insurance by the appropriate regulatory authority. The following factors are relevant:

1. Derivatives are not regulated in many developing and emerging market jurisdictions. In the circumstances, there is often no clear definition of “derivative” and, by default, an insurance-like contract would fall within the definition of an insurance contract.
2. Regulatory authorities in many developing and emerging market jurisdictions are anxious to avoid contracts being sold as derivatives to less sophisticated counterparties, such as a small MFI, as the purchaser does not have the protection provided to a policyholder under an insurance contract.
3. Although parametric or index-based insurance contracts are rarely used in mature jurisdictions, they are becoming more frequently used in developing and emerging markets. Regulatory authorities in these markets are therefore used to seeing parametric instruments classified as “index-based insurance” and a number of these jurisdictions are in the process of developing legal and regulatory frameworks to provide for index-based insurance.

If the local level contract is classified as insurance, the DRF would not be able to offer it unless authorized as an insurer. Even then, it would most likely require some type of local license. A contract that simply provides a cash payment on the triggering of an index is therefore, most likely, not a feasible option in respect of most MFIs.

It is likely therefore that a more conventional capital infusion will be required. Although definitions vary from jurisdiction to jurisdiction, regulatory capital is usually defined to include fully paid up ordinary shares and retained earnings. Some jurisdictions distinguish between different tiers of capital, or more simply between core and non-core capital. These jurisdictions often recognize as non-core capital or as a lower tier of capital other classes of share capital that provide the necessary degree of permanence, such as perpetual cumulative preference shares and certain types of unsecured subordinated debt. Other forms of non-core regulatory capital may also be recognized. Some jurisdictions recognize unsecured subordinated debt as the highest category of regulatory capital only if it is perpetual, i.e. it doesn't have a maturity date. For the lower category of regulatory capital, the subordinated debt may be required to be long-dated. A subordinated debt agreement may provide that the debt is convertible into equity, on the basis and terms specified in the agreement.

It is not unusual for the shareholders of a company, through a shareholders’ agreement, to agree to purchase further shares in the company in certain circumstances defined in the agreement. This could be considered in the case of an MFI that is a company. This could be a relatively straightforward agreement between the shareholders, the MFI being joined as a party to enable it to enforce the agreement. The contractual position would be complicated where the DRF is an entity as, although it would be providing the funds, it would not be a shareholder. Although a complication, this does not seem insurmountable.

In the case of VFI, not all MFIs are companies. This is likely to be the case in respect of other MFNs. A key concern in developing the FDRM system would be to ascertain how such non-company MFIs can be capitalized. The legal agreements would have to be tailored accordingly.

Where an MFI is subject to prudential regulation, ensuring that any capital infusion complies with the definition of regulatory capital in the jurisdiction concerned would achieve not only the economic objective of strengthening the balance sheet but would also assist the MFI to comply with its regulatory obligations by, for example, strengthening the capital ratio.

In the case of an MFI that is not subject to prudential regulation, regulatory capital will not be required. The capital infusion would not therefore have to fully comply with the definition of regulatory capital. This would enable types of normally non-allowable share capital, such as non-perpetual preference shares, to be issued, if that was to be considered appropriate. However, the definition of regulatory capital provides valuable guidance.

In summary, any agreement between the MFI and the DRF to provide an infusion of capital will most likely have to go beyond the payment of funds on the triggering of an event to avoid the contract being classified as an insurance contract. A more conventionally recognized form of capital infusion will be required, although that it may well be possible to provide this in the form of qualifying unsecured subordinated debt.

If capital is to be provided (if permitted) as unsecured subordinated debt, the contract between the DRF and the MFI would take the form of a single contingent loan agreement. The severity of the trigger would determine not just the amount of the loan provided, but also whether or not the debt created is subordinated. If the local legal and regulatory framework at the local level permits this, it would appear to provide a fairly straightforward solution. This would provide the MFN with significant flexibility, particularly if the MFN has the option to convert the debt to equity.

Portfolio Disaster Risk Management for an MIV

Section 9 envisions the establishment by an MIV of an Emergency Liquidity Offerings Fund (the ELO Fund) that, as the DRF, would provide emergency liquidity to participating MFIs affected by a natural disaster. The ELO would use pre-existing credit lines together with a risk transfer product with a provider such as Global Parametrics to fund the liquidity provided to participating MFIs.

The principal differences between the FDRM system envisioned for an MIV as against that for an MFN are:

- The objective for the MIV system is to provide liquidity only, there would be no infusion of equity capital. However, as discussed later in this section, the liquidity provided could, at least in part, be subordinated and therefore be classified as non-equity capital, and perhaps regulatory capital.
- It is envisioned that the liquidity will be provided by a separate Emergency Liquidity Offerings Fund (the ELO Fund), rather than a DRF.

Of course, the relationship between the MIV and participating MFIs is very different. An MIV will not typically have any ownership or equity interest in any participating MFIs and, consequently, it will not have the control over key decisions that would be expected to flow to a significant owner.

As with the proposed FDRM system, it is beyond the scope of this report to develop a prototype set of contracts, which will need to be developed on a case-by-case basis.

Outline Contractual Framework

Section 9 envisages that, at the global level, there would be a risk transfer contract with a provider such as Global Parametrics that will fund the provision of emergency liquidity.

Emergency liquidity will be provided to MFIs through loans, which will be governed by loan agreements entered into with each MFI. Each participating MFI would pay an access fee to the ELO.

The ELO

Although it is envisioned in Section 9 that the ELO would be a separate vehicle, as the DRF, it could be managed by the MIV as a segregated pool of assets. The decision as to how to establish and constitute the ELO is a critical first step and, in that regard, the discussion in this section on the establishment of the DRF is equally applicable to the ELO.

The Global Level Risk Transfer Contract

It is envisioned that the global risk transfer contract entered into by the ELO with a provider such as Global Parametrics would be sold as an OTC derivative, as in the envisioned FDRM system. The discussion in the previous section that refers is equally applicable to the ELO.

Local Level Contracts

It is expected that the local level contract between the ELO and each participating MFI will be similar to the contingent loan agreement to be developed under the FDRM system for MFNs. Consequently, similar legal and regulatory complications can be expected due to the different jurisdictions in which participating MFIs will be situated, their different legal and regulatory frameworks and the differing circumstances of each MFI. Separate local level contracts will need to be developed for each MFI.

It will be useful to undertake a similar initial scoping exercise, although with no requirement to inject equity capital, this could be more targeted. In particular, the issue of ownership of the MFI would not be so important. Given that MIVs do not typically own the MFIs which they support, and therefore do not have the control that follows ownership, the level of the MIV's control will depend entirely on the controls included in the local level contract. This will be an important consideration in drafting the contract.

As the FDRM system, it is envisaged that the agreement entered into between the ELO and each participating MFI would provide the MFI with the right to draw down on a line of credit on the basis of hard parametric triggers mirroring those in the global risk transfer agreement. However, the ELO could also consider including some softer triggers in the agreement to assist the MFI to manage its basis risk.

The contract would also set out the basis for repayment. As the FDRM system, repayment could be in accordance with a fixed pre-determined schedule or the obligation could be conditional on certain factors, perhaps related to the recovery of the MFI.

As indicated in Section 9, a prudentially regulated MFI that suffers a serious deterioration in its balance sheet, which affects its capital ratio, may not be able to incur the additional liabilities that would result from the provision of non-subordinated loan financing. Consideration could therefore be given to providing emergency liquidity partly in the form of unsecured subordinated debt, as envisioned in the FDRM system, which in many jurisdictions would be allowed as (non-equity) regulatory capital. An added flexibility tied to using subordinated debt is that it can also be issued as convertible debt.

If capital is to be provided (if permitted) as qualifying unsecured subordinated debt, the contract between the ELO and the MFI would take the form of a contingent loan agreement under which the severity of the trigger would determine not just the amount of the loan provided, but also whether or not the debt created is subordinated (as the envisioned FDRM system).

Section 12: Conclusions

This grant has been used for a variety of high value activities that are meant to enhance the resiliency of households, SME, and communities. These include:

1) developing a unique climatology data set for 24 low and middle and income countries and making them available for a wide audience as open source;
2) developing a new approach for modeling drought to complement other work underway between GlobalAgRisk and the Start Network (London); and
3) investigating how to structure FDRM solutions to support recovery lending among microfinance institutions.

Climatology Data

The grant funds have partially been used to build a unique data set for 24 low and middle income countries. These data are available as open source data for non-commercial purpose on Academic Torrents (http://academictorrents.com/). Details, background and the link to the data that are hosted on Academic Torrents can be found on the GlobalAgRisk homepage (www.globalagrisk.com). Subset of these data were used to design prototype FDRM solutions for the core work supported within this report.

The value of the open source data created with this grant is significant. As presented in Annex C, the Morrigu™ platform provides consistent climatology hindcast (reanalysis) data, on a global scale with high spatial resolution to support FDRM solutions for drought, extreme wind, excess rain, and extreme temperature. Its underlying inputs draw on the best peer-reviewed models, input data sets, and science.

The data sets are organized by political geographies which include administrative areas and populated places rather than points on a grid, and in such a way as to be readily linked to other databases. Unlike the typical binary data format used by climate models, which are hard to work with, the climatology data generated by Morrigu™ is made available via an SQL-compatible relational database format which allows for easy integration and querying by end-users. This makes it nearly trivial to link the climate data with external data sets routinely produced by governments such as economic data, crop production, etc.

The user-friendly format makes the climatology data sets highly valuable for in-country professionals wishing to integrate climatology data with their own data-sets. The improved accessibility by non-experts in climatology is important in a complex world of data sources. Among those who can use these data are sellers and buyers of risk transfer products, academics, and the many stakeholders working in low and middle income countries who wish to understand the risk from various extreme weather events.

A New Approach to Model Drought

It should be noted, that the most progress was made in developing the science to capture extreme drought occurrence. Soil moisture that was made available from the Morrigu platform was used to test a few new ideas. By using the climatology to develop estimates of soil moisture and matching those estimates with what is referred to in this document as the Crop Calendar Index at the administrative level, a country soil moisture index is developed by cropping season.

These data show promise when analyzed with advanced statistical methods. These methods are capturing the major historic droughts in key countries. Of note, the next steps in these methods as supported by a grant from the Humanitarian Innovation Fund is to forecast soil moisture conditions by administrative unit. This information can be highly valuable for early action for emerging food security problems that are driven by drought. Such information should also be highly valuable for farmers as planting season approaches and they consider making adaptive decision in their farming systems. This too has potential to aid in building more resiliency in low and middle income countries.

To be sure, this work has highlighted the need for similarly rigorous analysis and structuring to improve the excess rain and extreme wind offerings that were described within. While the science used for this study shows promise, more work will be needed to build the science for tropical cyclones, flooding and earthquakes.

Investigating FDRM Solutions for Recovery Lending

Returning to the core objectives, the work completed using the Rockefeller funds has the potential to bring substantial change in the way financial institutions manage natural disasters and, in particular, in creating the opportunity for supporting households, small and medium enterprises (SME), and communities in building resiliency. Providing loans immediately after a rapid onset event (e.g., tropical cyclone, earthquake, etc.) and potentially during a slow onset event (e.g., drought, certain types of flooding events, etc.) fits squarely with the Rockefeller's objective to build more resiliency among households and in communities. While the focus of this research is on financial institutions making loans in low and middle income countries, the principles and systems could be applied for financial institutions operating anywhere in the world. These efforts also fit directly with the 100 Resilient City (100RC) program. Households, SMEs, and communities need extra capital immediately after a disaster and having the wherewithal to finance these needs using FDRM solutions should be part of the 100RC programs.

Discovery using this grant has followed and reinforced the three step process for organizing ex-ante financing for natural disasters:

1. developing coordinated plans for post-disaster action agreed in advance;
2. creating the ability for fast and evidence-based response; and
3. using FDRM solutions to fund the response.

VisionFund has further tailored these steps to focus much more on the operational aspects of making FDRM solutions possible. In fact, VFI added some deeper context in their four step process (see Section 11). VFI continues this work with support from FMO and some ongoing discussions for support from the Asian Development Bank (ADB) to create what they refer to as the Asian Region Disaster 'Insurance' Scheme (ARDIS). Thus, the momentum created by this grant is highly significant. Furthermore, the intent of ARDIS is to extend into Africa and Latin America based on further proof of concept.

Section 11 on Implementation and Legal and Regulatory considerations is of high value for next steps. This section addresses some of the hurdles involved in creating the ability for fast and evidence-base response. Getting funds into many of these countries quickly remains a challenge. Issues such as exchange rates, local taxes, regulations, etc. will slow the fast response time if systems are not in place. Of equal importance, is to assure that the MFI has the capacity to implement a recovery lending program when disaster strikes.

The GRACE model(s) were used to analyze FDRM solutions throughout this document. The analysis proved insightful and reinforced previous work that followed portfolio and risk layering principles needed to optimize capital. Further analysis is needed to refine the understanding of how to use the various financing mechanisms for liquidity versus capital. There is limited rigorous analysis available to provide clarity in matching the liquidity and capital needs to various catastrophic events. In general, when the financial institution is operating with low capital or with a book of business that is already showing high portfolio-at-risk, the risk transfer product will be more important and, in some cases, likely a pre-condition for having an option on liquidity when there is a disaster.

Some insights that emerged from the legal and regulatory review offer some exciting flexibility in considering how to manage the capital versus liquidity challenge. With some careful construction, the same entity could supply both liquidity and capital via a single contract for contingent credit that triggers both senior and subordinated debt[21] based on the type of science presented throughout this report. More research will be needed to consider how to use subordinated debt and, in some jurisdictions, the flexibility to use this instrument to count as regulatory capital may not exist. It will take some time to work out the most effective mechanisms to use unsecured subordinated debt. The structures presented in Section 8 will work for a MFN that wants to start using FDRM solutions. And by the same token the MIV may not wish to take on this level of activity by offering contingent credit that can be provided as unsecured subordinated debt. Again, if this is the case, the MIV can start with offering only contingent credit as was developed in Section 9. Similarly, the preferences of the local MFIs would need to be considered. To become comfortable in providing access to liquidity based on disaster events, the MIV may require the FI to purchase risk transfer products that are structured in concert with their access to liquidity (i.e., using the same science and return period structures to layer the risk).

As indicated, VFI is in discussions with ADB about creating a structure like the disaster reserve fund (ARDIS) which would work beside an entity like Global Parametrics to provide the complete set of services needed to implement end-to-end FDRM solutions. ARDIS could be the legal entity for contracts with FIs. The concept would be to have a fund manager such as an MIV involved in managing returnable capital that would be used as the source of liquidity. As was illustrated in Section 10, having a regional or global entity that could pool more FIs for the liquidity risk of various FIs would improve the capital allocation much in the same spirt as the Global Parametrics model for risk transfer products.

Having an entity like ARDIS and one like Global Parametrics in partnership would increase the likelihood that the ideas developed with this grant would lead to systems that enable FIs to extend their lending into vulnerable regions and sectors and after a disaster remain adequately solvent and capitalized to be prepared operationally to extend recovery loans post-disaster.

[21] Subordinated debt could also be issued as a convertible debt to provide even more flexibility.

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Annex A: Can Microfinance Help the Poor Following Disasters?

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Recovery loans can be instrumental in helping clients rebuild. Learn more at #SEEP2016

"How can you lend to them? Won't it just make them worse off?" In the weeks following 2013's Typhoon Haiyan, these were questions that many concerned humanitarian responders voiced to me. Indeed, apprehension about affected people being burdened with too much debt was common and combined with concern about our local microfinance institution (MFI), Community Economic Ventures (CEV). CEV had immediately suspended repayments and interest among affected borrowers—which was highly appreciated, but costly—and saw a huge amount of loans at risk of not being repaid.

How could we lend to the affected communities when both our clients and our MFI were already in financial trouble?

After a Disaster; to Lend or not to Lend?

In the weeks following the storm, amongst vast destruction, CEV staff met with clients to better understand their needs. Three striking themes emerged:

- ✓ Affected people were appreciative of emergency aid, but acutely aware that it was temporary;
- ✓ They wanted to take responsibility for their own recovery, and as quickly as possible;
- ✓ There was a dearth of resources available for rebuilding livelihoods.

In fact, despite an unusually large response from the international community, only 60% of what UN OCHA estimated was needed, ever became available. Meanwhile, clients saw new business opportunities emerging and explained how they would use loans from their MFI to support recovery. We realized that if we took the safe route—suspend new lending, collect repayments and restart lending only as the situation stabilized—we would actually take money out of the communities at precisely the time that they needed it the most.

The question had changed: **How could we not lend?**

The Impact of Recovery Loans

In response, we created special recovery loans with larger and more flexible loan terms that loan officers could tailor to the needs of each borrower. Clients responded with quality demand that expanded our lending by 120%. Using the loans, clients rapidly rebuilt businesses, homes, and their local economies. In fact, clients overwhelmingly reported the loans were instrumental to their recovery—in many cases indicating that they had fully recovered or better in 18 months.

Indeed, the experience of CEV and other MFIs after Typhoon Haiyan demonstrated that microfinance can significantly contribute to the recovery of affected households and communities following a disaster!

Post-Disaster Lending: Why are MFIs Slow to Respond?

More recently, VisionFund launched recovery lending in Africa, Myanmar and Ecuador. Again, we have seen disaster-afflicted people seeking credit to rebuild, but MFIs struggling to lend. In fact, a range of studies by economists have confirmed this problem: lending to the micro, small and medium enterprise (MSME) markets typically declines post-disaster, despite an increase in quality demand.

Two key issues drive this market failure: fear of lending into a risky environment, and inadequate finances. In fact, one of the key strengths of the microfinance industry—the close link between clients and the MFI—becomes a problem when a disaster strikes. As many clients are affected and struggle to make their repayments, the credit providers themselves struggle and, consequently, cannot raise the capital they need to continue their lending.

A Sustainable Solution for Post-Disaster Recovery Lending

To provide post-disaster recovery loans effectively and quickly, MFIs must be able to adapt products rapidly, reinforce operations, and raise fresh capital. VisionFund, together with partners from the academic, insurance, humanitarian and microfinance communities, is building a Financial Disaster Risk Management (FDRM) solution that combines portfolio-level risk transfer with contingent liquidity. Furthermore, FDRM will provide in-depth understanding of exposure to risks, supporting preparation and mitigation against these hazards. Paired with quality lending, this FDRM solution will equip microfinance institutions to continue serving their clients through disasters, at modest fees of about 1% of the portfolio.

Isn't Aid Still Better?

Private and government aid, remittances and informal community systems all play a critical role in disaster recovery; however, they remain woefully underfunded against growing disaster risks. Recovery loans, meanwhile, are highly complementary to aid and bring new resources into the recovery. So the critical question is not if aid or lending is better, but how can we bring them together to provide more resources to the places they are most needed?

Our experience and the experience of many other MFIs has shown that microfinance can support client recovery through prudent, timely lending. Unfortunately, post-disaster lending is not the norm today as many MFIs face financial pressure and a dynamic environment that impede both their willingness and ability to continue lending. Modern financial and risk management tools, though, can equip MFIs to both be prepared for and respond to disasters.

The microfinance industry has been a pioneer in bridging private capital and social purpose, unlocking billions of dollars for the fight against poverty and becoming an integral part of poor communities along the way. A similar innovative approach to addressing disaster risk can bring yet more resources for client resilience and ensure that MFIs are ready to serve even in the most challenging times.

Working and Learning Together at #SEEP2016

You are invited to join this conversation at the 2016 SEEP Annual Conference, where VisionFund will be further "Exploring the Role of Microfinance in Resilience and Disaster Recovery" along with other experts. You will also hear from practitioners from GlobalAgRisk and UC Berkeley. Together, this panel of speakers will share new ways that Microfinance can assist poor communities recover from disasters and will also touch on how microinsurance and recovery lending can play roles in resilience, inclusion and recovery.

- Article contributed by Michael Kellogg. Michael is a part of the Insurance team at VisionFund International, which is building an innovative approach to supporting client resilience through market systems. With ongoing support from Professor Jerry Skees, DFID, Rockefeller Foundation, Asian Development Bank and FMO, VisionFund has reached over 20,000 clients in five countries following disasters during the past two years, and will soon cover more than 500,000 clients with its insurance-backed "Disaster Resilient Microfinance" approach.

Annex B: Case Study for Planning by VFI in Tanzania

This annex makes use of an excerpt from a blueprint prepared by VisionFund International in Tanzania to outline a possible set of coordinated plans for resilient financial services to assist clients during and following a natural disaster. The excerpt leaves out the discussion there on FDRM solutions as this current report provides updates that initial modeling work.

World Vision

for every child

For Every Child Campaign

INNOVATION FUND

Building Resilience with a Micro Insurance Component

Blueprint for Disaster Resilient MicroFinance: VFI Tanzania‡

November 2015

‡ Prepared by Joyce Kabura Njenga (Micro-Insurance Project Manager for Tanzania (VisionFund), Jason Hartell (GlobalAgRisk, Inc.) and Stewart McCulloch (Global Insurance Director, VisionFund).

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Executive Summary

An empowering long term relationship: VisionFund helps poor families by providing loans, insurance and a safe place to save. This empowers our clients to build their livelihoods and through this to care for and nurture their children. Our clients are mostly women who come to us as cohesive social groups looking to improve the prosperity of their group and their community. The core of our business grows from World Vision's Area Development Programs and then extends to others in and around those communities. Our care in building these groups is the strength of our model and adding new groups is how we grow. A bond of trust based on social cohesion is formed and a long term relationship fostered.

To be there through disasters: Many of our clients live in areas at risk to calamities such as floods, droughts, storms and earthquakes. These calamities are thankfully infrequent but can severely impact the ability of parents to provide for themselves and their children. We have asked how we can we help our clients and others in their communities in such exceptional circumstances. Frequently these disasters attract humanitarian relief from governments and organizations such as World Vision; but sometimes they do not. We have discovered that our services can be highly complementary to the relief efforts by adding further empowerment to the recovery of individual livelihoods and local markets. Insurance is part of the answer as to how we might help, as is access to savings, but only when we have provided these products and clients have had the foresight to use these important tools. We therefore have begun to develop an approach we call "recovery lending" that carefully provides meaningful loans to those who have been impacted and do not have sufficient aid, insurance or savings to recover. We have growing evidence that this approach can make a big difference to the recovery of their livelihoods following a disaster, providing another effective tool in the humanitarian toolbox.

To empower the resilience of the poor: Our clients prepare well for the shocks they see regularly. They diversify their sources of income, they use a variety of financial tools to manage their variable cash flows and they build trust within their community and with organizations like VisionFund. In a disaster their thrift continues when they make very tough choices about such important areas as food and education as they look to survive the stresses and strains caused. Equally, as the calamity passes our clients want to take advantage of opportunities to restore their self-sufficiency as rapidly as possible. We have discovered that we can give them some relief and an ability to take advantage of opportunities to recover:

- Existing Clients: We can give them short repayment breaks (grace periods) and perhaps longer to repay a loan to ease the strain on their finances. We have learnt that we must do all we can to avoid a non-payment or default as this can have challenging consequences for our clients' future financial health. We have also found that most clients desire to quickly restore the vibrancy of their lending groups by meeting, paying, and taking new loans as quickly as possible.
- Existing and new clients: We can give new or enhanced loans that clients can afford to rebuild their businesses or to diversify into sensible new areas. Our local staff and intimate knowledge of these communities means we can guide and advise our clients towards avenues where they can progress securely and while not incurring too much debt as they do this

A methodological approach: This is not a program or a product; it is an approach that uses our local knowledge and long experience to empower our clients and others to solve the problem they face and take the opportunities as they see them. This approach targets those with economic opportunity in order to rebuild local markets and thereby bring benefit to the economy of the community. Our responsibility is to ensure that VisionFund, with its various financial services, is fully present in the community both before and after the disaster.

Illustrative examples

***Ruth** has a fishing boat that was smashed by the typhoon. She is an existing client with a small loan and has been a good client for 4 years. Without the boat she will struggle to repay the existing loan and will not be able to restore her former livelihood which provided the majority family income and allowed her and her husband to send their children to the local school. A new boat costs $300 and the income from the boat would comfortably repay a loan and give the family an adequate income.*

Ruth was assessed within a few days of the typhoon and given a grace period while she sorted out her home and family's immediate issues. She applied for a recovery loan to pay for a new boat and to refinance her existing loan. A 12-month loan at a good interest rate was agreed and within 2 months she was fishing in her new boat and providing for her family.

Our work with the fisherfolk, fish traders and fish processors has helped restore the local fish market and reduce fish prices. Meanwhile, the local boat builders report revived businesses and income, which they then use in the fishmarket and with other local shopkeepers who have been able to restore their stock also using VisionFund loans. There is still a way to go to fully rebuild their homes and recover other lost assets but alongside humanitarian relief efforts people across the community are empowered to continue along that road.

***Joyce** keeps goats and grows maize. The drought has been very bad over the last few weeks and months and as far as Joyce knows, is set to continue for some time. She has a small loan from VisionFund taken to plant the maize which is now close to harvest, but yield will be very low and could be nothing if she can't harvest soon. She is left with no choice but to begin to sell her goats at a time/place that will not get the best price and so will be forced to cut back on education fees and food intake. Joyce has also been a good client for 5 years.*

VisionFund has looked at the best weather information available and are confident the drought is ending in the next 8 to 12 weeks and that certain crops will be able to be planted at that point. We give a small loan to Joyce to help her salvage what harvest she can and transport some goats to a market that will give her a better price. This together with a short grace period allows her to manage much better through the crisis and then later start a new loan to replant after the drought subsides. This new loan has been agreed to be repaid only on the harvest of the crop. With this package Joyce's children have continued their education and the family have remained well fed.

Recovery Lending is not just theory. Following Typhoon Haiyan in the Philippines on 8 November 2013 we worked with World Vision's humanitarian teams to provide recovery loans to over 4,000 clients benefitting nearly 10,000 children. 96% of those clients reported that their livelihoods were restored with our loans and half said that incomes had fully recovered or better.

Recovery Lending Complements World Vision's Humanitarian and Resilience programs. Using humanitarian funding for recovery lending has the benefit of both rebuilding livelihoods directly and multiplier effects that benefit the relevant value chain, local market and whole community. As a sustainable enterprise, VisionFund also has the opportunity to borrow further, multiplying donated funds up to 4x with commercially borrowed funds. Finally, the majority of donated funds will also be repaid and then recycled back into the community as future loans, allowing more families and communities to benefit from the same humanitarian funding. In effect, $100,000 allocated to recovery lending could become as much as $1,600,000 cash provided directly into communities through loans over 2 years. In summary, recovery lending is a powerful new tool to improve financial resilience and accelerate recovery as part of a response.

Our aim is to make recovery lending "business as usual". Microfinance institution's success is closely tied to the success of its clients. When clients are adversely impacted by such calamities, the institutions must make financial provisions for losses, on schedules often dictated by their country's financial regulator. This unfortunately places financial pressure on the MFIs and often forces them to reduce lending to clients just at a time when the need for it is increasing. Our work is looking to show that recovery lending is both helpful to clients and good business, reducing the losses for the institution as well as helping their clients rebuild livelihoods. We are also developing a way of using insurance and other financial tools to be able to guarantee we can give our clients a recovery lending response. We hope through this work to establish a new approach to helping clients in disasters across the microfinance industry.

Finally, and in conclusion, our view of **financial resilience** has five components:

1. Household resilience supported by savings
2. Household resilience supported by insurance
3. Community resilience supported by remittances
4. Government and NGO provided humanitarian cash based relief
5. Livelihood restoration through recovery lending

Questions and answers

1. Why lend to those in need? Should we not give them aid instead?
   Recovery lending adds to the funds available from aid and often gives individuals larger amounts than otherwise would be available to restore their livelihoods. This approach both complements existing support mechanisms and empowers individual families and their communities to decide how best to drive their own recovery with sums large enough to have a substantive impact.

2. What interest is charged and why is it value for money?
   VisionFund charges competitive interest rates commensurate with the cost of providing small loans sustainably. Both client surveys within VisionFund and global research has consistently shown that for the vast majority of clients we serve their primary challenge is ***access*** to financial services. Our research also indicates that this problem is exacerbated in a disaster context, as existing lenders reduce the lending available just as the need is greatest due to their own financial challenges and fear of lending into an unknown environment. VisionFund's lending process ensures that the loans provided are affordable within the family's cash flow and support the intended business activities.

3. Do people confuse grants and loans and so not repay the loans?
   This is possible and others have reported such cases. But with care and our disciplined recovery lending approach we have growing evidence that this is not a major issue. In most instances of failed programs however, post-program reviews have shown poorly implemented approaches that did not clearly communicate to the clients that the tool being used was a loan. VisionFund's programs ensure that clients are oriented to the loans that they are offered, they understand and agree to the terms of the contracts, and in many cases clients complete basic financial literacy training before they are eligible to apply for loans.

4. How do you know you are not harming a client with debt they can't afford?
   Over indebtedness is a risk that VisionFund normally mitigates through detailed evaluation of a client's assets and cash flow, and regular monitoring through face-to-face visits to the client's business and home. In disaster contexts, we continue to closely evaluate capacity of clients to repay, but we also adapt our procedures to consider the income and assets pre-disaster as well as the impact from the disaster. Further, VisionFund employs experienced loan officers who are frequently members of the communities that they serve, and are consequently familiar with the earning capacity of the various activities that the community undertakes. Using both strong procedures and local knowledge, VisionFund has the capacity to supply loans that are tailored to the needs of each family and affordable according to their cash flow.

5. Humanitarian programs target the most affected individuals, usually the "poorest of the poor". These are likely to be different than the people usually targeted by micro-credit organizations. Will this project actually benefit the most-affected people?

VisionFund intentionally targets poor clients. In many countries, we use a tool called "The Progress Out of Poverty Index" (PPI) to monitor the level of poverty of all clients to ensure that we maintain targeting of very poor clients as new client's enter the program and that poverty levels improve over time as the clients' progress with the program. In many countries, 60-75% of clients entering the program live below the $2.50/day line, and as many as one third may be below the "Extreme Poverty" line. We have found that entrepreneurial ability and capacity to grow are not necessarily tied to current poverty levels.

6. Can VisionFund do this in countries outside of its current operations?
   Only on an advisory capacity to local MFI partners as yet.

Introduction

The poor are often found in the places most vulnerable to climate and other risks that impact their ability to sustain livelihoods and advance economically over long periods. Despite low initial wealth and low of access to affordable formal risk transfer, poor households have developed a rich variety of individual, mutual and community-based risk management strategies that provide critical household "resilience" and safety net protection against many idiosyncratic shocks.

Microfinance seeks to expand the economic and entrepreneurial potential of the working poor by providing reliable access to credit and savings deposit services. These services are also mechanisms for enhancing household resilience against negative income shocks. In addition, many new micro-insurance initiatives have been developed to transfer household risks, mostly idiosyncratic "personal disaster" risk such as death, disability and sickness.

Unfortunately, many household strategies are susceptible to correlated disaster risk that overwhelms the poor's individual and collective action efforts, and exposes them to the prospect of poverty traps and slow economic recovery. Microfinance providers are rightly concerned about the risk exposure of their clients since their well-being has a direct consequence for the health of the institution. Several recent high profile weather disasters have highlighted this joint vulnerability, showing that stressed microfinance providers are often not able to provide the continuity of services especially needed in a community following a disaster.

This paper outlines a blueprint for "disaster resilient microfinance" that includes new micro-insurance for individuals and agricultural enterprises, and a new approach to disaster recovery lending services to help clients regain their livelihood following uninsured asset losses. It also describes a financial disaster risk management (FDRM) system that backstop the microfinance provider's portfolio, provide for service continuity and to fund these exceptional lending services to its clients. We recognize an incremental structure to overall resilience and we adopt the following view of where microfinance services, including the new approach described here, and other efforts contribute:

1. Household resilience strategies including the use of savings,
2. Micro-insurance where it is available, purchased and triggered,
3. Community resilience strategies including remittances from family,
4. Government and NGO in-kind and cash-based relief when provided, and lastly
5. Livelihood restoration through disaster recovery lending funded by FDRM.

Risks Faced by the Working Poor

The types of risks faced by the working poor are characterized here in descending order according to (1) the degree of frequency (i.e., with more frequent risk being more certain to impact a household), and (2) in ascending order according to the anticipated severity of the event. This characterization of frequency and severity of risk will be referenced throughout the paper. Bear in mind the reference is of events having mostly unplanned financial consequences for a household.

1. *Life cycle risks* include the potential need to supply a dowry, pay for education, or take in displaced or disabled family members. These risks are encountered by almost all households and occur with frequency.
2. *Death risks* are unavoidable but have a less certainty of timing than life cycle events. The associated costs may be simultaneously one time and small (funeral costs) and ongoing and large (replacement of an income stream supplied by household member).
3. *Property risks* include events of theft, damage, or loss of family or business assets. Property risks are far more uncertain than life cycle or death risks, because both timing and whether the event will occur at all are unknown. Property risk costs vary with the value of the lost asset.

4. *Health risks* from accidents, illnesses, and injury of household members vary in cost, depending on the nature of the event. Health risks are difficult to predict in advance and are regarded by low-income households as generating a greater degree of uncertainty than most other risks.
5. *Disability risks*, in contrast to sporadic occurrence and short duration of health risks, are a continuing problem. Costs from disability risks are ongoing and may include treatment expenses and lost income. While higher in cost than health risks, their likelihood is more uncertain.
6. *Mass/correlated risk*s include natural disasters draught, epidemics, and other major events that cause substantial and simultaneous losses for a large part of the population. While their effects on individual families can be placed in the five categories just defined above, mass covariant risks are considered separately because they are infrequent but affect many people and whole communities at one time, and often cause multiple losses within the same household.

Correlated Risk Consequences for Microfinance

Microfinance organizations and their clients are vulnerable to correlated weather disasters. Particularly with agricultural lending, widespread weather related losses negatively impact the financial institution's lending portfolio when many clients experience repayment difficulties and, in extreme cases, are forced into default on their obligations. Microfinance organizations can also incur substantial additional operating expenses during a disaster.

This costs and consequences of arrears and loan default often leads to non-price credit rationing or even temporary exit from the credit market until portfolio performance improves.[1] During a natural disaster crisis, however, is precisely the time when functional lenders and ample credit are most important for coping and recovery of households, and for reducing the impact of the disaster shock on the economy.[2] For those organizations having social mandates to empower the working poor through reliable access to credit and initiatives to expand agricultural lending, as does VisionFund, financial risk management solutions need to be developed to assist their clients avoid financial ruin and to protect the institution from insolvency during a disaster event.

The range of options that a microfinance organization ordinarily has at its discretionary disposal to respond to a natural disaster event is fairly limited, and in many cases there is no established protocol that enables a modified response at the client level. Some standard mechanisms used to protect the viability of the institution include mandatory credit-life insurance coverage in the event of the death of the client, self-contained reserve funds as a percentage of the lent value, mandatory collateral savings as a percentage of the lent value, subscription to loan guarantee funds, and maintaining a high capital ratio and liquidity buffer. All these add to the cost of borrowing and, in the latter two examples, constrain overall access to finance. One can sketch an outline of what actions are possible using the standard menu of risk management tools, and informally compare them with more comprehensive financial solutions:

- Imagine a correlated disaster event, such as a drought or flood, inducing a 10% portfolio at risk (PAR>30) that is rising. There is also the perception that balloon loans held by some agricultural clients will not be repaid on time.
    - In this situation the existing available tools will help lessen the impact but the MFI will likely still experience liquidity problems resulting from a disruption in revenues, higher expenses, and withdrawal of voluntary savings. Capital impairment will rise quickly limiting the ability of the MFI to continue lending even at previous levels. Anticipated arrears in agricultural balloon loans (where

[1] Norell, D. 2001. "How to Reduce Arrears in Microfinance Institutions". *Journal of Microfinance* 3(1):115—130.
[2] Khandker, S.R. (Mar. 2007). "Coping with Flood: Role of Institutions in Bangladesh." *Agricultural Economics* 36 (2), pp. 169–180.

they exist) will create a second shock to the portfolio. Loan guarantee programs will not provide relief until default processes are exhausted sometime into the future.

- Now imagine that the MFI has access to additional liquidity, as some might have through exercising a prearranged loan from a liquidity facility, or other means:
  - The liquidity can enable the MFI to reschedule/restructure loans and grant limited grace periods to those most impacted until the disaster passes. Prudent rescheduling (to the extent that doing so does not simply transfer default risk to the future) can help lower the portfolio at risk and associated loan-loss allowance.
- In more severe cases, consider how a capital injection designed to correct a portfolio imbalance could influence the range of actions taken by a MFI. Capital injection might come about through additional donor financing, contingent arrangements with commercial banks or other investors, or through an ex ante designed mechanism.
  - Additional capital directly offsets loan-loss provisions, helping slow or stop the fall of capital adequacy ratios. With sufficient capital, the MFI can begin refinancing loans and issuing new loans to those clients who need investment credit to recover their livelihood or who need additional funds to prevent further loss. Over time, compromised clients will begin repaying allowing loan-loss provisions to be written back, further strengthening the MFI's capital standing. Depending on the mechanism, the capital injection is either repaid over time or is retained by the MFI, enabling a permanent increase in the level of leveraged lending.

The sections that follow explore how the latter two outcomes can be accomplished via the use of a well-designed FDRM system encompassing a liquidity fund and parametric weather insurance that operates at the global level of a microfinance network, such as VisionFund. Such a structure enables the pooling of catastrophic risk that brings pricing efficiencies and protection that would not be available to a microfinance institution acting on its own.

An important feature of the FDRM system, as a consequence of the parametric component, is the ability to provide timely information about a disaster event, in some cases even as or before it is unfolding. This information will enhance the decision-making ability of the microfinance institution when it takes action against a disaster event.

Disaster Resilient Microfinance (DRMF)

VisionFund has recent experience with post weather disaster lending, or "recovery lending", following the 2011 Horn of Africa drought and the 2013 super typhoon Haiyan strike on the Philippines. Both of these interventions sought to provide additional tailored lending to disaster-impacted households to help them recovery their livelihood activities or to start new enterprises. A combination of a new loans, modified repayment schedules, release of savings collateral, and refinancing to consolidate existing debt enabled many household to remain active microfinance clients while empowering them to lead their own recovery, and to do so more rapidly than they would have been without the assistance. Repayment history, and client recovery, of these financing interventions has also been excellent.

One common thread of these prior experiences is that the intervention took place largely after the disaster was well underway or already passed. Disaster responsive financial services, however, takes on a broader challenge by asking how and when can VisionFund enable client led resiliency efforts in those instances where early action can reduce household consequences of a natural disaster? This approach incorporates lessons from emergency humanitarian action and applies them to microfinance. Early and well-funded humanitarian action based on forecasts and/or prompt intervention of slow onset events such as drought are estimated to strongly reduce costs and human suffering compared to interventions that take place after the fact.[3,4] Disaster resilient financial services is then the combination of early incremental actions and recovery lending.

We examine early intervention initiatives and held discussions with loan officers and operations personnel to identify where and how new incremental microfinance products and services can help households prepare for and exit from an evolving natural disaster. In designing response options, care is made to observe the following:

- Client led (Empower the client to make choices and take action)
- Do no harm (Diligent in preventing unsustainable indebtedness and default)
- Preservation (Maintain the client relationship through the disaster event)
- Sufficiency (Help the client cushion enough of the impact to enable them to recover a sensible livelihood after the disaster)
- Sustainability (Do not jeopardize VisionFund's ability to provide continuity of service)

Topography of Disaster Resilient Microfinance

The range of disaster resilient financial services should be well targeted to specific purposes while also being reasonably simple and consistent with current lending processes and procedures. The primary objective is access to financial services that are responsible for availing suitable credit and related instruments that can help clients respond to the disaster crisis in a way that helps them from descending into a poverty trap situation where long term recovery and growth become impossible. A prominent example is the distress sale of productive assets to overcome the short- to medium-term effects of drought. The proposed lending services are therefore not free humanitarian aid provided by the MFI. Clients are still expected to repay their obligations on the agreed time and in full. The disaster interventions are meant to be client led, whereby they apply for and make the business case for these lending services.

Different MFIs even within the same network may have slightly different implementation approaches and preferences to the following disaster resilient financial products. These are noted as appropriate for the VisionFund East Africa Region. At a general level, there is also a strong maternalistic sense of solidarity with clients, and a corresponding diligence in avoiding client over indebtedness and other efforts to level the playing field in times of extreme disaster need.

In the introduction there was outlined the ways that additional liquidity and capital funding flowing into the MFI can progressively give it greater flexibility and scope in offering enhanced disaster response financial services. The succeeding topography generally follows a similar structure; however, it is preceded by the introduction of new and existing micro-insurance options under consideration by VisionFund

Micro-Insurance Protection

Micro-insurance is a risk transfer device characterized by low premiums and low coverage limits designed for low-income people not served by typical commercial insurance schemes.[5] Cost efficiency is key to the success of micro-insurance therefore polices are usually simply designed and take advantage of existing financial service delivery channels. For non-life coverage in particular, streamlined administrative procedures and total-loss style policies helps avoid the huge cost of indemnity based claims processes. Micro-insurance providers have also

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[3] Venton, C., C. Fitzgibbon, T. Shitarek, L. Coulter, and O. Dooley. (June 2012). "The Economics of Early Response and Disaster Resilience: Lessons from Kenya and Ethiopia." Economics of Resilience Final Report. UK Department for International Development (DFID). 84pp.

[4] *A Dangerous Delay.* (January 2012). Save the Children UK and Oxfam.

[5] See the following for an overview of the history of microinsurance: http://www.microinsurancenetwork.org/brief-history#sthash.9DFrvFL7.dpuf

been at the forefront of information technology advances to achieve further distribution efficiencies and to rapidly increase scale. The typical poor household uses microfinance to access credit and savings services and now micro-insurance, which is less of a new phenomenon to these clients. Most microfinance institutions deliver a variety of insurance products through their existing agent networks. The most common arrangement is product bundling where the particular microfinance institution holds a global policy for the clientele and the insurance product is bundled with lending and or savings.

Enhanced Credit Life

The traditional bundled micro-insurance product used by microfinance has been credit life insurance, a policy that indemnifies the lender for the outstanding loan balance in the event of client death. On occasion it may also provide a lump sum death benefit to a designated beneficiary. Micro-insurance has since evolved to include many of the risk faced by the working poor that were outlined in the introduction, and are frequently presented as "enhanced" with optional add-ons to standard credit life cover.

The new micro-insurance product being considered as part of enhanced disaster related cover for VisionFund clients is a type of property insurance. Specifically, it is fixed sum insurance for the total loss of the asset used as collateral against a microfinance loan. Covered perils include fire and flood. The product not only serves to protect clients against idiosyncratic loss, but also as the first line of defense against certain correlated disasters.

Livestock Insurance

Microfinance, like much traditional lending, allows for the physical asset being purchased to serve as the collateral against the loan. In agriculture, the collateralization of an asset such as a cow is a new phenomenon that is complicated by the "perishability" of the asset. For example, where livestock owners are encouraged to invest in breed improvement through the purchase of new foundation stock and the use of modern husbandry techniques such as synchronization and embryo transfer, micro-insurance can play a pivotal role in backing the collatorization of the underlying asset and facilitating credit availability for the investment.

VisionFund is investigating alternative livestock insurance products specific to this need, which provides indemnification in the event of theft or death of covered animals. Such a policy should reduce the risk and expand lending for herd improvement. Specific terms, exclusions, and veterinary requirements are still under consideration. As with the property insurance, the cover protects the household from both idiosyncratic and correlated losses.

Savings, Grace Periods and Restructuring

Savings Mechanisms

Savings is the first line of defense to manage small losses and minor liquidity constraints within the household. Savings vehicles can be informal, such as so-called community "merry-go-round" schemes, or in the form of assets and materials (i.e., livestock, other physical assets), as well as formal savings with a financial institution. While these savings are an important means of coping in the immediate aftermath of a disaster event, individual and community schemes will often fall short of needs.

In exceptional cases among disaster-affected clients, the MFI may decide to grant access to the obligatory savings (loan guarantee savings) associated with outstanding loans, but this policy is likely to vary among individual MFIs or VFI regions. The additional funds, which can vary from 5% to 20% of the loan's principle value, can prove to be a valuable supplement to external aid and other assistance directed towards the client. However, should new lending require an obligatory savings deposit, clients will need to be counseled of this before they decide to divest if that is an available option. Release of obligatory savings can also worsen the MFI's liquidity position and increase the loan loss allowance by the same percentages.

More generally, consideration may be given to other kinds of voluntary savings vehicles for disaster resilience as well as providing a "safe place" to store transformed assets (e.g., proceeds from destocking or sale of other physical assets) that may take place during a disaster event. To be attractive, the savings product will need to provide competitive interest rates and convenient access through agency banking, although it's primary attribute should be the security of cash funds during the uncertainty of a disaster. Minimum deposit and time-dependent incentives could be considered to encourage savings of larger amounts for longer periods. Other savings incentive structures might include the bundling of disaster savings with enhanced personal or property insurance options. Marketing efforts should incorporate financial literacy and disaster planning training to help clients better use formal savings approaches in conjunction with their more traditional, but vulnerable, forms of asset holding.

Grace Period and Loan Restructuring

In some circumstances a client will have experienced a moderate disruption due to the disaster event that, while not creating a need for additional funding, may cause the client to temporarily fall behind in loan payments. An example may include temporary market access problems that create a liquidity crunch either on the part of producers or downstream traders and processors. In many cases a grace period and negotiated restructuring of the loan that offers some repayment flexibility may be sufficient to keep these clients from falling further behind and becoming a more serious default risk. The grace period avoids imposing a punitive burden for a short delay in making repayment among those affected by a disaster.

A 'natural' grace period can occur when loan officers are delayed in arriving to clients for loan collections because of disaster related travel disruptions. In other instances, where the loan is already in arrears, or where impact assessment shows evidence that a client's livelihood has been disrupted, a payment grace period can be offered during which time no penalties or additional interest are charged. The duration of a grace period can be longer the greater the assessed impact but rarely will exceed two months, where the total number of skipped payments depends on whether the payment frequency is weekly or monthly. Within the East Africa Region, current information management systems are currently designed such that the provision of grace periods is administratively complicated and best accomplished by cancelling the original loan and issuing a new loan (i.e., a rescheduled loan).

For some clients, a grace period may be insufficient to help them become current with their loan obligation. Providing that a client assessment shows willing repayment ability and a strong probability of the current livelihood activity resuming, the remaining loan balance could be restructured more extensively that shifts or extends the loan term, or other modification that slightly lowers the periodic installment. To change the structure of a loan also involves replacing the original loan with a new loan. During disaster episodes, a modified fee schedule could be introduced that reduces the up-front costs, but ordinary interest would apply as usual.

Rescheduled loans would move from being in arrears and subject to loan loss provision to the MFI's restructured portfolio, improving the capital balance. Grace periods, lower fee structures and any other delay in payment would impact the MFI's current liquidity. But if the benefits of rescheduling are realized, the loans should return to making revenue contributions within a short time.

"Recovery Lending" Scenarios

The following are all new or additional lending mechanisms that can take place during and after a natural disaster. This lending is directed at the uninsured losses experienced by clients. Very rarely will new lending accompany loan forgiveness even during a disaster, although secondary mechanisms such as specialized individual insurance or collateralized micro-insurance could be used to payoff existing loan balances.

The goal and primary benefit of these new lending options is to ensure *continuity of access* of the working poor to credit during times of natural disaster. The new products will need to be priced in a manner that is consistent with prudent sustainability of the financial institution now operating in a difficult and higher cost environment. Lower than break-even pricing could put the MFI in an even more vulnerable position when a large block of new lending does not make a positive contribution to income while at the same time increasing the leverage of existing capital. The use of the market interest rate before the disaster should be the norm for initial pricing which also includes margin to restore capital and cover additional costs.

In the exceptional disaster circumstances there may be some scope for adjusting the loan access fees to lessen the impact on clients so long as there exist the resources to also sustain the MFI, although discounts are not the objective of the lending. Rather, the access fees may become part of the overall loan in lieu of an upfront payment. In a similar manner, the rules regarding collateral at least among otherwise known and good clients may be modified to reflect the fact that many clients will likely have just experienced significant assets losses.

The various VFI regions may have different preferences that slightly alter the direction taken under disaster resilient microfinance lending, just as they might for release of obligatory savings. For instance, within the East Africa Region there is a strong preference for universal flat rate interest as clients readily grasp the charging calculations. Other VFI regions may include declining balance methodologies in some circumstances. In addition, disaster lending must be strictly "asset or income backed" with there being little tolerance for loan diversion to non-investment or non-livelihood purposes.

To summarize, the benefit of reliable credit access during disasters involves prudent new lending with the following properties:

- Market interest rates as before the disasters
- A fair access fee rolled into the loan
- Flat rate for transparency and client understanding
- Profit to cover additional costs and restore capital

Repair and Preventative Loss Lending

Repair and preventative loss lending involves modest additional financing to be used for quickly responding to moderate damage, losses, or threats that will help prevent greater loss later or enhances current season productivity. Examples of repair and preventative loss include:

- Restoring to service damaged assets such as storage and business buildings, farm equipment, irrigation infrastructure, silted water pans, toppled water storage, replacement, pumping equipment, fencing, etc.
- The purchase of inputs and services used to prevent additional losses in the current season or year. Examples may include replacement of lost fertilizers, and clearing of drainage systems to prevent further damage. Extreme weather can promote pests and disease prompting the need for additional plant protection and veterinary services. Other inputs and services may relate to destocking strategies, limited crop replanting and post-harvest handling such as drying services.

Repair and preventative loss lending is meant for immediate activities that act on the current season or production cycle. They are possibly structured as a balloon type for agriculture if necessary and within credit policies. These are relatively small to modest loans that, when combined with an existing loan obligation, should represent a viable repayment probability given the anticipated benefit of the funded repair and preventative loss activity. Repair and preventative loss lending is additional lending and will have the usual effect on the MFI's financial ratios and capital requirements.

Diversification Lending

The purpose of diversification lending is to assist damaged clients pursue an intermediate and less vulnerable enterprise as a temporary or transitional source of income until the disaster passes and their primary livelihood can be restarted. Diversification lending is particularly relevant for disrupted seasonal based livelihood activities and other situations where there is a rational for postponing restoration. For example, information coming from the FDRM system may indicate that a drought will continue through a subsequent production season, therefore discouraging lending for rain fed crops or extensive forage dependent livestock. The client, however, may have an alternative income source that is less vulnerable that could be enhanced with modest investment to provide additional cash flow through the duration of the disaster crises.

Diversification lending is a new or refinanced loan that can be either of a balloon or regular repayment type depending on credit policies and the proposed diversification activity and its anticipated cash flow characteristics. Diversification lending would be best paired with financial and/or technical, market or extension-based training (perhaps via World Vision outreach into disaster affected areas) to give the client the best possible advantage to succeed. This is particularly important, and likely should be a requirement, for proposed activities that are outside of the client's experience and more akin a brand new business venture. Diversification lending is viewed as lending for a new start-up activity and therefore considered more risky and subject to greater scrutiny. Given existing debt and disaster-induced stress, the client and the MFI cannot afford to have the new venture fail. As new lending, the MFI will need to have sufficient supporting capital, although the magnitude of the increase may be partially offset by the delay in lending to primary livelihood activities.

Recovery Lending

Recovery lending involves having available new financing after a natural disaster has passed for existing and potentially new clients who have significantly lost their livelihood and need to make a substantial investment in order to restart and begin recovery. These loans, for which clients must apply and go through an assessment process, are strictly for asset replacement and business investment that result in reestablishment of income streams, not for disaster coping or diversion to other purposes. Overall loan size is likely to be similar in magnitude to usual working capital lending due to individual repayment capacity, but could be somewhat larger depending on the needed investment. The loan term can also be somewhat longer, up to 12 months, depending on the amount borrowed, the anticipated return on the investment, and the cycles of the overall recovery that may be longer during a disaster. The longer loan term also results from efforts to keep monthly payments at a serviceable level when recovery lending involves refinancing existing debt obligations into the new loan. Recovery lending will usually be the largest portion of disaster resilient microfinance activity following a disaster

Sequencing Disaster Resilient Microfinance Interventions

The proceeding tools can be used in a number of different combinations and/or sequences depending on the disaster event, disaster severity, and client segments impacted—the sequencing that will be presented is not a strict formula but rather a guide that may be adjusted by the disaster affected microfinance institution. While loan officers may have considerable discretionary authority, in order to make decisions sustainable for the MFI, they will need to ask a series of questions when considering how to approach a damaged client and what can be offered. Items to consider include the seasonality of income, structure of existing loans if present, repayment ability with existing debt, the degree of damage to a client and the number of clients damaged, and the amount and type of available resources, the credit risk of existing and possibly new clients, and what are the added risk implications of the new financial services in the disaster operating environment.

A number of assumptions are first provided as a reference point in the use and sequencing of the new financial products, a stylized schematic is outlined and finally followed by a number of possible scenarios.

Assumptions

- Impact description:
  - No impact: Even within affected areas, some clients will not have experienced disruptions that are severe enough to threaten their livelihood or repayment ability. They will not fall in arrears.

  - Minor impact: Some clients will experience disaster disruption either directly or consequentially where their repayment ability or income generating ability may be served by some minor temporary assistance. The temporary disruption implies possible minor arrears occurrence.
  - Severe Impact: Some clients will experience severe direct disruption to their livelihoods and are likely to need significant additional resources to restart and recover a livelihood. The condition implies high probability of falling into arrears and default without assistance, but the clients are otherwise historically considered creditworthy.
- Impact distribution: The distribution of impact will vary depending on the type of disaster. The initial assumption is of equal proportions between the impact types (i.e., one-third for each)
- In the East African context, agricultural lending is two-fold:
  i. Where agriculture is recognized as part of households larger income and hence clientele borrowing for other purposes and using agriculture earnings to repay, in such instances borrowing is for the other need such as school fees, business loans, etc. This lending follows a periodic repayment structure.
  ii. Where one is borrowing directly to undertake an agriculture activity such as rice farming and this is predominantly extended as balloon type repayment structure of 6 to 8 months duration coinciding with the cropping cycle. This agricultural lending is highest for rice, maize, and poultry production.
- The timing of the disaster event in the repayment cycle will impact loan repayment ability and consequential debt burden.
- Moral hazard will be present. Some unaffected clients will attempt to claim damage and consequently defer prompt repayment of their loans. Detecting and controlling moral hazard during disaster will likely increase loan monitoring costs.
- Client assessment following the disaster will likely be delayed by 3 to 5 weeks, depending on location (rural areas being more difficult) and staffing levels.
- The client type is assumed to be reasonably well diversified across income generating activities, neither the poorest nor most dynamic of VFT's client segments (i.e., the Riziki segment). This is the norm as for agricultural lending and VisionFund Tanzania insists that clients demonstrate multiple sources of income in addition to the activity that is attracting the lending.

Sequencing

The sequencing schematic give in figure 3 is differentiated between rapid onset (e.g., excess precipitation leading to flood, severe windstorm) and slow onset (e.g., drought) disaster events to give a view of how the suite of disaster resilient financial services can be used in a variety of combinations to address differing client experiences, while also broadly conforming to a standard operating protocol.

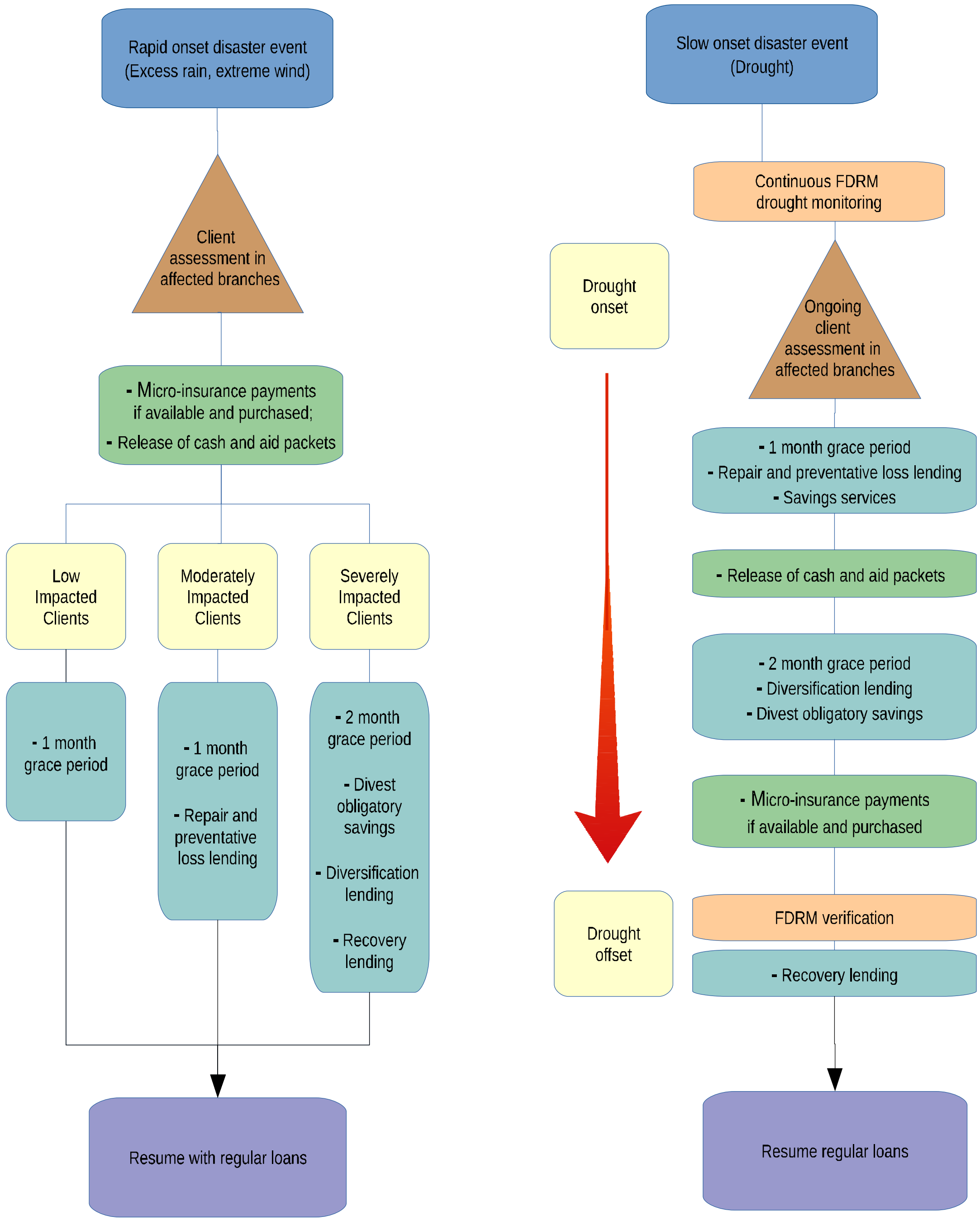


Figure 1 Sequencing in the use of disaster resilient financial products.

Stylized Examples

The following examples take the schematic given above and flesh out possible response options and scenarios for a number of disaster events affecting different clients.

Overland Flood Events

Flood events can have widely variable impacts depending a client's location in the local topography, and the depth, swiftness and duration of floodwaters. For agriculture, precipitation that induces flood can bring a productivity boost, depending on timing, and recharge local water supplies. In addition to direct asset damage, floods can also contaminate local water supply, impede regional transportation, and contribute to disease and insect problems.

Impacting Crop Farmers

Imagine a flood event that affects part of a farm enterprise temporarily. Extreme local and remote rainfall generates overland flood that washes away newly established crops in low-lying areas and causes heavy silting of water pans used for vegetable operations. Assume also the farmer is currently holding a balloon loan that was used for initial land preparation, planting and fertilization. Providing that it is sufficiently early in the season, the lost crops could be replanted using assistance from a modest *repair and preventative loss* loan, where the new loan and old loan are refinanced together.[6] These funds could also be used to purchase labor for the unexpected maintenance cost of the water pan repair to ensure sufficient water capacity to extend into the dry season. Wetter than usual conditions can also promote greater disease and pest problems, whereby the extra cost of plant protection can also be financed with the new loan. This use of modest additional financing should help reduce farm losses compared with a situation were no additional action is taken, and enable the repayment of the combined balloon loan at the end of the cropping season.

Should clients experience a widespread, lengthy and/or deep inundation, agricultural losses could be much more significant reflected in little or no primary crop production in the current season (again, depending on timing), accompanied by destruction or damage to farm structures or equipment, loss of inputs, and death of animals. Payments for livestock and property loss would be expected if *micro-insurance* were available and purchased. Otherwise, uninsured losses could be addressed with 2-month *grace periods* as appropriate and/or *recovery lending* to help the client revive their primary livelihood after the flood recedes.

Impacting Shop Keepers and other Village Enterprises

Flood affecting villages and peri-urban areas will create livelihood problems for clients through direct loss of assets such as inventory, equipment or even the building. Indirectly, there may be a temporary loss of markets when transportation is hindered and when customers are also struggling with flood impact. For those in the latter circumstance, a single month *grace period* and loan restructuring may be sufficient to help bridge the gap in business cash flow. Where greater or total loss is experienced, a 2-month *grace period* and/or *recovery lending* to address the uninsured asset losses could help vitalize livelihood recovery. As before, if *micro-insurance* were available and purchased, it would be lead the way in asset replacement.

Flash Flood Impacting any Primary Producer

Flash flood impact can be quite variable across space or even over a single farm. Often it will not accompany significant local precipitation and frequently occurs with little or no warning. Flash flood can occur following

[6] Different options exist for financing depending on the cash flow of the particular client. The repair and preventative loss loan could be repaid on a regular basis if it helps preserve ongoing income sources, such as vegetable plots. Regular repayment may also be preferred if the combined new and old loan are larger than can be supported by the primary livelihood activity at the end of the cropping cycle. Loan officers can work with their clients to help ensure there is access to needed resources while at the same time safeguarding timely repayment.

an intense downpour where there is not sufficient absorption capacity and where the topography favors quick drainage. While flash flood can occur any time, it is likely more common during El Nino and other atmospheric anomalies that promote sudden and intense rain bursts.

Consider a severe flash flood event that destroys farm structures (e.g., water pans, chicken houses, storage buildings, etc.), carries away livestock and washes out crop plantings. First, individual asset protection via *micro-insurance*, if available and purchased, would ideally make first payments toward asset and livestock replacement. The MFI could then assist livelihood recovery from the uninsured losses. If damage is not catastrophic but important for current production, the client could be offered a *grace period* of those loan obligations on a regular repayment structure, as well as a *repair and preventative loss loan* to maintain or enhance the value of remaining production and productive assets. In a more serious event having greater losses, a 2-month *grace period* and/or a *recovery loan* may be needed to begin restoring the client's livelihood.

Drought Event Impacting Pastoralists

A severe drought that reduces the productivity of grazing land can have far reaching consequences for pastoralists. Cattle and other livestock are generally viewed as a savings vehicle and their loss represents a real loss of wealth as well as of future productivity when foundation breeding stock are destroyed. Pastoralists have many coping strategies for moderate drought including the splitting of herds and migrating to less affected grazing lands, and purchase of fodder. In a severe drought these actions are generally insufficient. If herders decide to divest before livestock succumb to the drought, they will often find that the terms of trade have moved against them since many herders are also selling livestock at the same time.

Disaster resilient financial services could be employed to cushion the impact of a drought for a pastoralist in the following manner. First, the FDRM system that monitors drought and rainfall contracts for VFI would provide early indications that a possibly severe drought was developing. Loan officers could provide this information to the herder client who, armed with this knowledge, could move to reduce losses through early destocking of slaughter animals before prices begin to drop. Based on the drought projection, the MFI could also make available *repair and preventative loss* lending to finance extra costs of the destocking, such as for transportation of animals to market. At the same time, the financing could be used to purchase extra fodder, watering rights or equipment, and veterinarian services in order to preserve core breeding stock and household animals (i.e., for milk). The herder could also take advantage of *savings services* to hold the remaining proceeds from the destocking after repaying the short-term loan. These savings are available for household consumption needs until the drought cycle breaks. The FDRM system drought monitoring would provide loan officers and herders with reliable indications of whether pasture conditions were sufficiently improved to begin rebuilding the herd. If so, *recovery lending* for herd reestablishment could be offered, along with *livestock micro-insurance* particularly if herd genetic improvement is a component of restocking. This sequencing of reliable extreme weather information and specific financial services (as well as extension and *market* information where available) could help a herder transition into and out of a drought episode with a reasonably intact livelihood.

Drought Event Impacting Crop Farmers/Confined Livestock

Severe drought events manifest themselves slowly; gradually worsening until a full-blown food security crisis has developed. Early warning systems, including drought monitoring from the FDRM system, can help detect evolving drought events enabling early humanitarian action as wall as incremental and proactive interventions by the MFI to help their clients transition through the event.

In the stages, there may be some crop failures at the beginning of the season. Crop emergency failure is not exceptional when there is variation around the usual onset of the rain season, and replanting credits are sometimes sought to reestablish a crop However, the use of FDRM system information and other drought warning systems might indicate that the early failure is just the beginning of a substantially below average rain season. In this case the use of replanting credits is not recommended since subsequent crop failure will only increase a client's debt burden. Instead, a *grace period* and/or *repair and preventative loss lending* could be advisable to address problems that will only become more chronic as the drought worsens. For example, small investments in irrigation technology may stretch the remaining water resources used for vegetable production. Water purchase may be necessary to ensure the survival of certain perennial crops such as cashew. Poultry and other confined animal keepers may be advised to stockpile feed before prices rise as well as secure reliable water sources.

When the primary livelihood activity is heavily impacted and where a client must wait for the next viable planting season, *diversification lending* may be considered for an alternative drought resistant enterprise to provide an income stream. Diversification lending is considered by some MFIs to be similar to lending for start-up businesses and therefor considered to be higher risk. To help lessen the risk, this type of lending may be more successful when aligned with retraining programs offered through World Vision or even other NGOs responding to the drought event.

Aside from very severe drought scenarios, there may still be limited crop harvest even without financed preventative loss activity. Ideally the lower supply will provide higher prices to producers enabling them to repay at least a portion of their (balloon) loan. These loans can be provided with a grace period and rescheduled, possibly to a regular repayment type with lower installment. Finally, in each of the cases above, once a drought has broken *recovery lending* can be deployed to assist growers in reestablishing their primary cropping activity. Again, the FDRM system information and other drought monitoring services should be referenced to provide confidence in the likelihood of a return to usual weather patterns.

Conclusions and Next Steps

In this paper we have argued for a disaster resilient microfinance approach that empowers VisionFund clients to seize recovery opportunities in order to rebuild their livelihoods, local markets and the local economy after a natural disaster. Disaster resilient microfinance is a component of financial resilience, working alongside community resilience, humanitarian and resilience programs, and disaster recovery efforts. VisionFund should continue to progress its savings and micro-insurance strategies to strengthen household resilience. In addition, further development of recovery lending will ensure that clients have access to credit when needed for replacing lost assets critical to their livelihood. To help maintain continuity of microfinance service and to help fund recovery lending, a market-oriented FDRM system has been designed that blends a rapid disaster recovery fund with a parametric insurance product. Together these address MFI liquidity and capital erosion impacts that frequently emerge during a natural disaster. Preliminary financial modeling suggests that a pooled approach among VFIs global network of MFIs can provide affordable and self-sustaining benefits.

VisionFund has a DFID funded initiative about to commence to demonstrate the applicability of recovery lending to floods and droughts in East Africa in response to the emerging El Niño threat. Additionally, in collaboration with VisionFund's development partner GlobalAgRisk, we have a Rockefeller funded initiative to refine the design and applicability of the FDRM system among our initial pilot country MFIs to further validate its feasibility. After successfully demonstrated and validated, the subsequent steps will be to take the fully complete FDRM system to market for the insurance cover, to initiate the disaster response fund, and to implement in-country disaster resilient microfinance approach.

Annex C: The Science and Data-driven Foundation for FDRM Solutions

This Annex is a companion piece to the open access weather data and catalog provided as a component of project work performed by GlobalAgRisk, Inc. under a grant from the Rockefeller Foundation. That project, "Financing Recovery Lending to Build Resiliency", focuses on the application of financial disaster risk management (FDRM) solutions to liquidity and capital erosion problems faced by microfinance when hydrometeorological disaster impacts client livelihoods, and how ex-ante financial solutions can be used in the form of 'recovery lending' to help clients recover from these events. Underpinning the ex-ante financing is a parametric weather risk transfer mechanism that uses modeled data from numerical weather simulation, rather than on data collected from specific weather stations. One reason identified in the project for adopting this approach, particularly in a developing country setting, is that high quality weather data sets of sufficient length are extremely difficult to obtain and maintain for the purposes of risk transfer. As described within, the numerical weather simulation approach provides an opportunity to overcome this important constraint, as well as to potentially extend data coverage world-wide.

The purpose of this document is to provide an overview of the scientific data-based approach adopted for the purpose of quantifying weather hazard risk in low and middle income countries. The scientific modeling platform used for this work (Morrigu™, developed by Enki Holdings) is innovative, and expands on the traditional weather hazard modeling capabilities typically utilized in the insurance and weather trading markets. Given the importance of climate modeling and weather forecasting technology for this approach, this document anchors on a broad description of climate models as well as the practical aspects of climate modeling and climate data generation which are pertinent to the work undertaken during the project and help to inform the use of the open access data.

Hazard Risk Data: The Basis for Hazard Risk Transfer[1]

Any actuarially-sound risk transfer proposition must be based on the accurate quantification of risk. Risk quantification is key to existing markets in natural-hazard risk transfer such as the property insurance markets as well as the weather markets, and it is also key in developing risk-transfer products for low and middle-income countries. Both of these markets involve the transfer of risk associated with exposure to natural phenomena such as flooding, earthquake activity, or extremes in wind or temperatures. In property insurance markets, risk is transferred from policyholders to insurance companies and possibly to reinsurance carriers. In weather markets, exposure to environmental risks such as extreme (low or high) precipitation, wind or temperature is transferred between hedgers, market speculators and market-makers. In either case, both the scaling and pricing of risk transfer is determined on the basis of a statistical estimate of risk.

A statistical estimate of risk is obtained via a risk distribution, which expresses the likelihood of a hazard event, such as a specific temperature, amount of precipitation, or an associated monetary loss, in the case of traditional insurance. Most often, however, the risk distribution is expressed as the likelihood of *exceeding* a certain hazard or loss level. For example, a single point on the risk distribution may indicate the probability of exceeding a specific temperature, or inversely, identify the temperature which is

[1] An in-depth discussion of risk quantification and risk data needs, as related to parametric weather index insurance can be found in GlobalAgRisk Inc.'s 2010 *State of Knowledge Report - Data Requirements for the Design of Weather Index Insurance.*

exceeded with a certain likelihood (e.g. with a probability of 10%). Whichever way it is expressed, a risk distribution is the basis upon which risk-transfer transactions are priced using actuarial principles.

Risk modeling practitioners commonly characterize long-term risk probabilities in terms of 'return periods'. The return period is simply the expression of a probability in terms of the time scale associated with the data from which the probability is estimated. For example, let's say one is using annual temperature data to derive the probability of exceeding a specific temperature level, and this probability is estimated at 10%. This information can be used to form the expectation[2] that, going forward, the likelihood of exceeding this temperature in any given year is 10%. This statement can be expressed slightly differently by saying that the temperature level in question is, on average, will be exceeded once every ten years. Thus, the return period in this case is 10 years. It is simply the reciprocal of the probability value (in this case, return period based on annual data = 1/0.10 = 10 years).

It is useful to look to the existing property catastrophe insurance market as well as the market for weather risk-transfer to understand the tools and data these markets rely on to develop weather-related risk distributions. Both markets are relatively young (on the order of 20 to 30 years) and both markets have, at one time or another, been limited by the availability of risk data.

The weather derivative market is very much reliant on historical weather data records to derive weather risk distributions. One of the simplest but widely used risk and valuation method is 'burn analysis', which simply considers the empirical distribution of the weather variable of interest. Because the weather market is highly concentrated on the more economically developed nations of the world, it is relatively well-served by historical weather data. A significant segment of the weather trading market deals with exchange-traded derivative contracts linked to major North American and European cities. These contracts typically have payouts referencing major airport-based weather stations which have been in operation for long periods of time, and thus for which historical weather data exists. The part of the weather market which is not exchange-traded, also utilizes long-standing weather stations around locations of interest and, if necessary, make use of spatial interpolation techniques to use weather data from several stations both for historical risk analysis and contract trigger definition.

The property catastrophe risk market, which is really a segment of the property reinsurance market, is most developed in North America, Europe and Japan and is concerned with risk-transfer associated with the 'peak perils' i.e. those natural catastrophe hazards which are responsible for the most significant losses to the insurance industry (tropical cyclones, earthquakes, extratropical storms, and to a lesser extent tornados and flooding). This market started developing relatively quickly in the 1990's on the back of significant catastrophe-related loss years and was aided by the development of commercial catastrophe risk modeling tools, using historical event data to estimate risk[3].

The methodologies among commercial risk modeling approaches share the similarity of involving the formulation of hazard-specific stochastic event catalogs. Stochastic event catalogs consist of a database of simulated and historical hazard events, such as tropical cyclones or extratropical storms, where each event is characterized in terms of physical characteristics describing hazard severity and, in the case of tropical cyclones, horizontal path over the earth's surface. The collection of events in each stochastic

[2] This expectation assumes that future temperatures are adequately characterized by historical data.

[3] The interaction between the growth of the property catastrophe market and the evolution of catastrophe risk models is described in Muir-Wood R., 2016. The Cure for Catastrophe. Basic Books.

catalog is carefully controlled such that the entire stochastic catalog becomes a statistical representation (distribution) of the hazard in question. The determination of the stochastic catalog is typically based on historical data (e.g. a database of historical tropical cyclone events), supplemented with scientific judgement regarding the likelihood of extreme events not captured by historical observations, as well as the application of statistical modeling to describe the theoretical distribution of events. This basic stochastic catalog methodology suffers from the limited extent and inconsistent quality of historical event records. The most extreme events are underrepresented in historical records. Furthermore, the older historical data is, the more likely it is to be of poor quality, or inconsistent with more recent observation methods.

The stochastic catalog methodology reflects the common actuarial approach of using a statistical risk distribution to estimate risk probabilities. In recent years, the two commercial catastrophe modeling firms have begun to improve certain hazard risk models by calling upon physics-based dynamic models of hazard processes. For example, Risk Management Solution's extratropical cyclone model for Europe utilizes a Numerical Weather Prediction (NWP) model to help build its stochastic catalog of storm events. In this case, NWP is used to better describe the complex spatial characteristics of extratropical storms which are significant in describing their damage potential. Another example of supplementing the basic stochastic event catalog methodology with physics-based models, is the case of storm surge caused by tropical cyclones approaching coastal areas. Both commercial vendors have integrated in their stochastic catalog methodology, the results of dynamic storm-surge models which simulate the interaction of surface wind and pressure fields with the ocean surface and coastal bathymetry.

Despite the evolution of catastrophe risk modelers' methodologies to generate basic hazard data (via stochastic catalogs), the models made available by these firms are limited to the most economically significant risks to the commercial markets, and thus focus mostly on those weather risks pertinent to the property insurance sector.

Going Global with Modeled Climatology Data

As described above, much investment and effort has been spent by sectors of the insurance and financial communities to develop risk models or risk profiles of a limited number of weather-related hazards. These efforts have been focused on the most commercially-significant weather risks and have developed over time based on individual 'peril/region' models which are marketed and licensed on an individual basis. The science and technology supporting the commercial catastrophe models has led to hybrid models which rely largely on the availability of high-quality historical data-sets, which are then supplemented using either physically-based models, or expanded to form stochastic event catalogs which combine historical data, scientific insights and statistical modeling.

This approach is clearly not scalable to regions of the world and natural phenomena which are not well covered by the availability of long historical weather records.

As indicated, commercial catastrophe risk modeling vendors have slowly started to adopt physically-based dynamical models of geophysical processes, but in a fairly limited manner, supplementing their existing modeling methodologies rather than replacing them. This has in part been facilitated by the increasing availability of inexpensive computing power, allowing commercial firms to run some of these models in-house on increasingly powerful computer systems.

The type of physical processes modeled by some of the dynamical models already adopted by commercial vendors (e.g. dynamical flood, storm-surge, and regional NWP models) are not dissimilar, in a very general sense, to the range of physical processes involved in weather forecasting and climate modeling i.e. modeling phenomena over the earth's surface, in space and time. It is not surprising then that the next logical step in the development of hazard risk modeling is to look into the capabilities of weather forecasting and climate modeling, which can be applied at global scales and simulate a range of weather variables (and thus potential hazards) using a single model. Even for the relatively 'simple' and localized hazards of interest to weather-trading markets (such as temperature and precipitation), the notion to make use of climate models was still considered remote just a decade ago[4]

Although climate models, and associated numerical weather prediction technologies have become increasingly capable and accessible outside of academic research groups, the climate modeling landscape is highly fragmented, with a multitude of alternative models and a broad-range of data sources and processes used to initialize and 'drive' these models. Hence, to-date, most applications of climate modeling to risk hazard assessment have typically been very limited in terms of geographic scope and hazards considered. As will be further described later in this document, the Morrigu™ platform is unique in that it provides an environment through which disparate climate models and related data-sets can be integrated using common data interfaces or formats, thus solving the many compatibility issues which otherwise limit model and data selection.

Climatology provides the type of hazard risk data upon which risk estimates can be developed. Unlike the stochastic catalog approach of commercial catastrophe risk model vendors, which rely significantly on databases of actual historical events, climate models are developed to accurately reflect historical weather in a statistical sense. In other words, climate models are generally not configured with the expectation that simulations reproduce exact historical events in space and time. However, they are expected to generate an accurate representation of the statistical characteristics of historical weather. The stochastic catalog method underlying catastrophe risk models and the application of climate models to derive risk estimates both attempt to achieve the same goal, however, it is important to distinguish the differences between the two.

The key distinguishing feature of climate models is that they attempt to model the physical processes underlying weather dynamics. Climate models are parameterized such as to represent physical processes as accurately as possible, over broad geographical regions or even globally, as well as through time. If successful, a climate model then captures the entire dynamical range of physical processes underlying weather, including extreme conditions. In other words, an accurate climate model should be able to capture the entire distribution of weather conditions, based on its accurate representation of physical processes. Climate models are 'dynamical' models in that they express the dynamics of physical processes.

The stochastic catalog approach is a statistical one, rather than a dynamical one. It begins with a database of observed, historical events, and builds the catalog through statistical methods with the goal of capturing an accurate representation of the distribution of possible hazard events. Although the stochastic catalog approach is guided by physical insight, it does not involve modeling physical processes

[4] See for example: Stephen Jewson et al. 2005. *Weather Derivative Valuation: The Meteorological, Statistical, Financial and Mathematical Foundations*. Cambridge University Press.

directly. Stochastic catalog models arrive at a statistical distribution of hazard events by focusing on historical events and guided by physics. Climate modelers, on the other hand, derive statistical distributions of hazard events based on physics, guided by historical data.

As will be discussed in more detail in the next section, there exist many types of climate models and these continue to evolve and improve over time. Thanks to the development of high-quality historical climate records ('reanalysis' data-sets, also discussed in the next section), climate modelers have common reference points against which to compare the performance of different models. Nonetheless, different climate models can generate different results. Given any weather variable, one climate model may exhibit a systematic bias relative to another model. In terms of risk hazard assessment, such a bias may not be problematic if both models generate similarly shaped statistical distributions for the given variables of interest. The reason for this is that a systematic bias, which does not otherwise affect the shape of the statistical distribution, maintains the relative probability distribution of the variable of interest. This is one reason why, in practice, the comparison of hazard estimates across models is best carried-out based on probabilities or return periods, rather that absolute physical quantities (such as temperature or precipitation).

The innovative approach to hazard risk data developed during this project centers on the generation of modeled historical weather (climatology) using state-of-the-art climate models and data-processing tools. The objective of this approach is to use one of several well-known climate models and simulate past weather using a consistent methodology, on a global scale. This approach, made possible via GlobalAgRisk's partnership with Enki Holdings, represents a significant breakthrough in natural hazard risk assessment capabilities: Not only is the approach scalable globally, but the hazard risk platform developed by Enki Holdings (**Morrigu™**), integrates a range of climate modeling related processes and data sources, which until now had not been available to the natural hazard risk community.

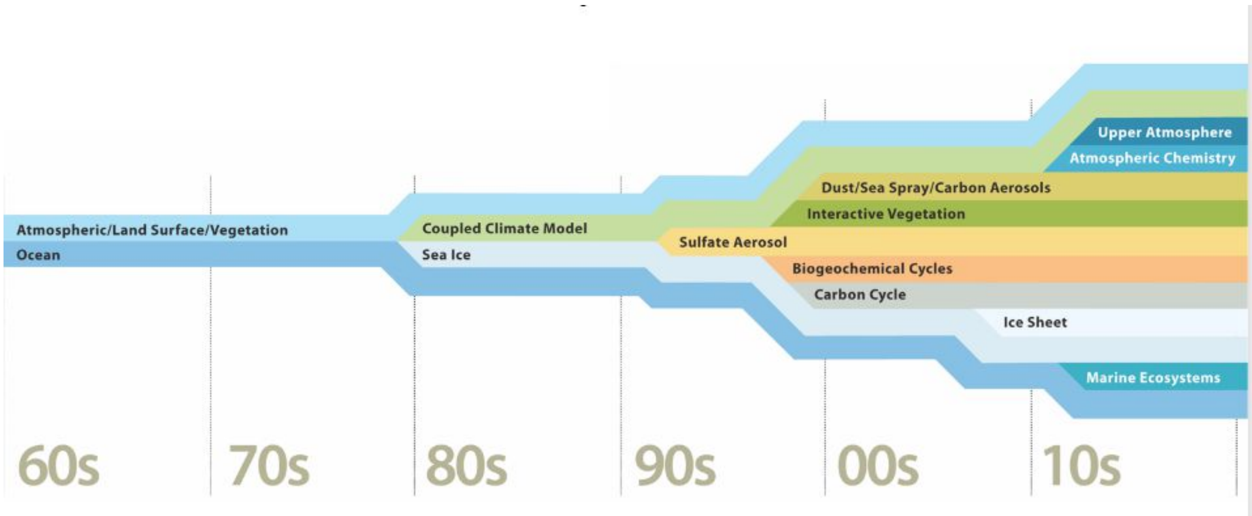
To better understand Morrigu™ and its innovative features, it is useful to review what climate models are and how they are used.

A Brief Introduction to Climate and Numerical Weather Prediction Models

Model Architecture and Development

The development of short-term weather prediction models and climate models, which typically operate over longer time-frames, are very much intertwined and sometimes even hard to distinguish. For the present discussion, we are referring to **General Circulation Models**[5] (GCM) which can model the dynamics of weather processes on a global scale. Today such models are typically '**coupled'** models in that they integrate the dynamics of the atmosphere with an increasing number of other very significant geophysical components such as land processes, ocean processes and circulation, and sea-ice processes amongst others. All these physical processes have a part to play in driving weather over both short and long time-scales. The evolution of climate models and the cumulative integration of additional physical processes is show in Figure 1. What this diagram illustrates particularly well is the recent and rapid evolution of climate modeling technology.

[5] https://en.wikipedia.org/wiki/General_circulation_model

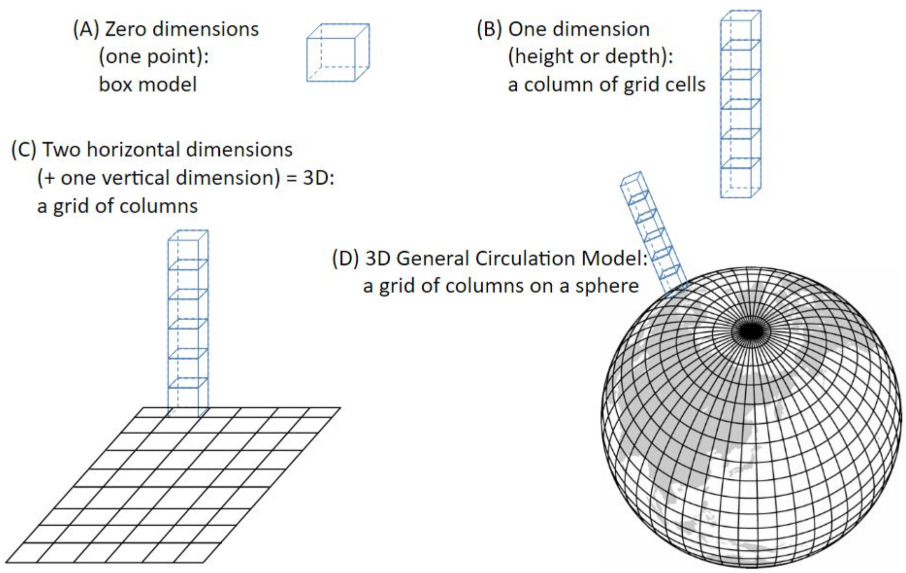


[Source: Gettleman, A. Rood, R. 2016. Demystifying climate Models: A User Guide to Earth System Models. SpringerOpen] [6]

Figure 1 - Increasing complicity of couple-climate models, which integrate an increasing number of important physical components driving weather and climate processes.

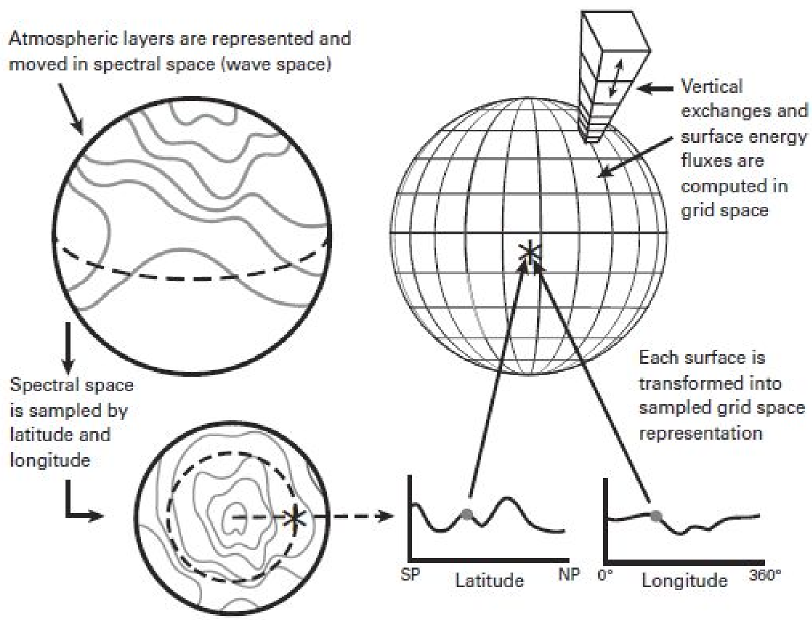
Climate and numerical weather forecasting models generally follow a three-dimensional **grid** structure covering the entire globe, in the case of global or general circulation models. Figure 2 depicts the simplest Gaussian grid-based structure of climate models, across all three dimensions. Note that the vertical dimension extends below as well as above ocean surfaces. Another way climate models or some of their components can be structured is on the basis of a so-called **spectral grid** representation, which are harder to visualize or depict. The spectral representation of physical variables over the earth's surface in frequency-space ('wave-space') and leverages the fact that many physical phenomena (related to fluid-dynamics) exhibit wave-like motion. In fact, the picture is a little bit complicated in that climate models may use both a Cartesian grid structure in the vertical dimension, but a spectral grid structure in the horizontal dimension (see Figure 2(b)). Yet other types of grids are so-called adaptive grids, whereby grid cells or 'boxes' vary in size depending on their location over the earth's surface.

[6] This open-source reference is available for download at http://www.demystifyingclimate.org/home



[Source: Gettleman, A. Rood, R. 2016. Demystifying climate Models: A user Guide to Earth System Models. SpringerOpen]

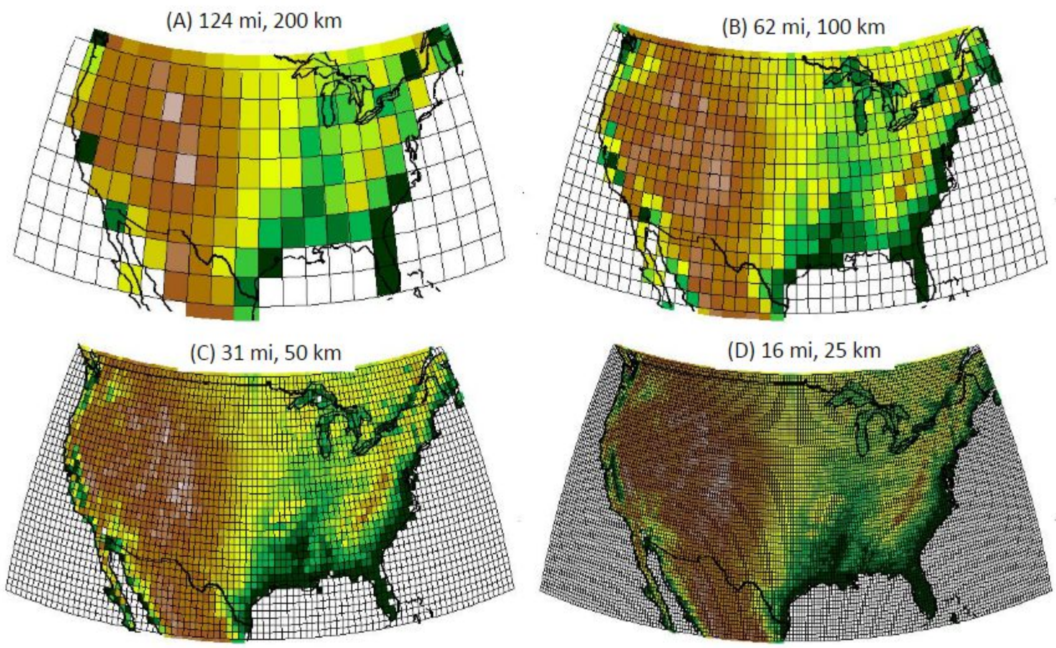
Figure 2(a) - GCM model dimensions and grid structure.



[Source: Edwards, P.N. 2010. *A Vast Machine: Computer Models, Climate Data, and the Politics of Global Warming*. MIT Press.]

Figure 2(b) - Spectral (horizontal) and Cartesian (vertical) grid structures.

Most climate and numerical weather prediction models can be operated at various grid **resolutions** (see Figure 3), depending on the specific application for which they are used. Furthermore, to complicate the matter further, the various components of coupled-models may in fact make use of different grid-types and grid resolutions. This implies that such complex coupled models must involve a very significant amount of work in managing and translating data that must be passed between model components at every step of a simulation run. Occasionally, a global climate model might be configured to run at a certain spatial resolution, yet a much higher resolution analysis is required over a specific geographical region within the global grid. A number of techniques have been developed allowing modelers to use the lower-resolution dynamics generated by the climate model, and **downscale** it to a higher resolution over a specific region of the simulation grid. These techniques may involve the application of higher-resolution physical modeling within the regional area of interest (**dynamical downscaling**) or make use of statistical techniques to essentially interpolate the dynamics within individual grid cells (**statistical downscaling**)



[Source: Gettleman, A. Rood, R. 2016. Demystifying Climate Models: A user Guide to Earth System Models. SpringerOpen]

Figure 3 - Comparing different horizontal grid resolutions. Grid cell dimensions are (a) 2 degrees (200 km), (b) 1 degree (100 km), (c) 0.5 degree (50 km) and (d) 0.25 degree (25 km). Degrees are expressed on a latitude basis.

The essence of a climate model is the dynamical modeling of physical processes across its three-dimensional grid structure. Each component in a coupled-model (e.g. atmosphere, ocean, land, sea-ice cover) involves the solving of mathematical equations which describe very specific physical processes across space (grid structure) and time (divided in simulation time-steps). Figure 4 depicts the conceptual relationship between the various components of a coupled model, across the grid structure and in time.

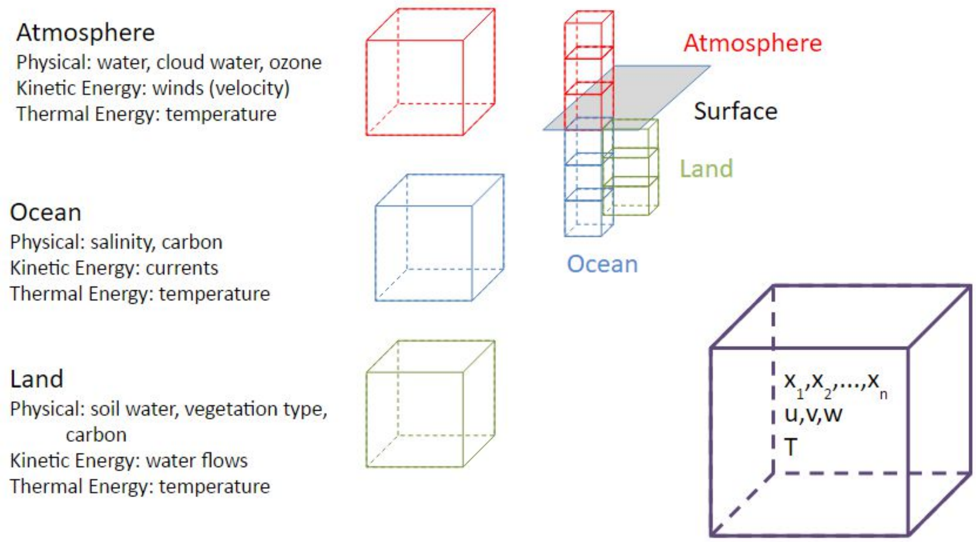
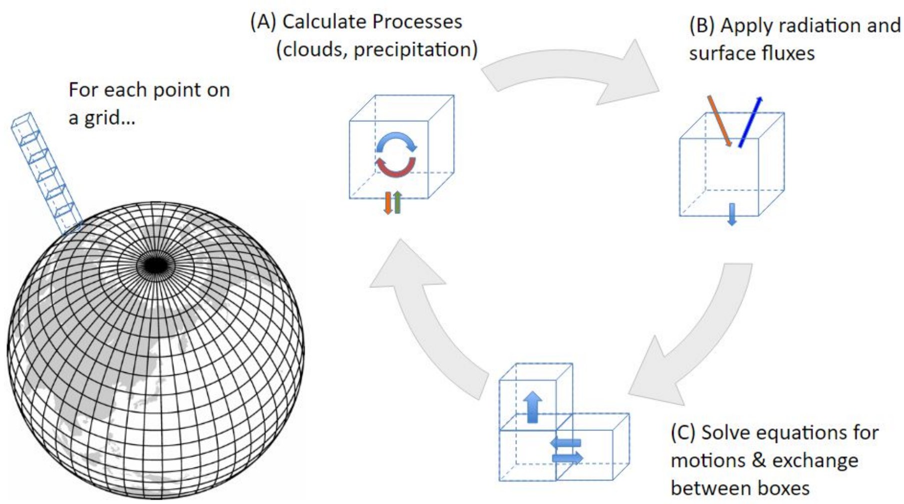


Figure 4(a) – Each component of a coupled-model has its own grid representation, within which component-specific processes are modeled.



[Source: Gettleman, A. Rood, R. 2016. Demystifying Climate Models: A user Guide to Earth System Models. SpringerOpen]

Figure 4(b) - Simulation involves solving equations and passing information across the entire grid at each time-step.

Data Assimilation

The evolution of climate models depicted in Figure 1 was not only driven by advances in scientific understanding of physical processes and the availability of high-performance computers, although those were two important factors. Another very significant factor in pushing forward the development of climate models was the availability of sufficient high-quality weather data which could be used to characterize global weather conditions at any one point in time and also across time. This data is critical for the setting-up (**initialization**) of initial atmospheric conditions which kick-start the simulation process. Furthermore, accurate observational data is needed to define any **boundary-conditions**, which represent the state of the atmosphere or other physical process at the boundaries of the model's coverage. For example, global circulation models are bounded on either limit of their vertical component (sea-floor and upper atmosphere). Non-global, or regional models, have boundaries at the limit of their horizontal reach as well. Of course, each physical component of a coupled-model (atmosphere, ocean, land) has its own need for boundary conditions and initialization data specific to its physical processes.

The general process by which climate models are initialized is termed **data assimilation.** Data assimilation is a complex process whereby a large number of observational data sources, across a vast array of physical processes, and involving many scales of temporal (sampling frequency) and spatial resolutions, must all be integrated in a coherent manner to initialize model components. This necessarily means a considerable amount of data-processing work, necessary to present the data to the various components at the appropriate time and space resolution. Data assimilation involves a variety of data sources, from radiosondes to satellite and aircraft reconnaissance data, as well as traditional land-based weather station data. Some of this observational data, such as satellite data, was not available prior to the 1950's, which also highlights the high-level of dependence between climate modeling science and technology.

Data assimilation is critical to both running long-term climate modeling exercises, as well as for the much shorter-term operation of weather forecasting models which run on a near-continuous basis to compute real-time weather conditions and generate forward-looking forecasts. Both types of model application (climate vs. real-time forecasting) place different demands on the data assimilation process. Climate model simulations are long-term exercises which typically compute high-resolution climate conditions over very long time-scales. These simulations can run for days, weeks or months, all the while requiring periodic updating via data assimilation. Because of the long simulation times, these models are subject to data assimilation inconsistencies caused by the occasional changes in data quality. Considering the large volume of data involved in data assimilation, such inconsistencies are not infrequent, and can be the result of changes at the level of individual data sources (a satellite, aircraft, or weather station) due to technical issues (e.g. failure), or even changes in measurement sensors or equipment. Any such changes require some level of correction to the data, to maintain consistency across time.

Shorter-term weather forecasting models, on the other hand, are much more dependent on the continuous, near real-time, availability of data assimilation output, but less exposed to the potential inconsistencies mentioned above. The main point is that climate models are highly-dependent on observational data, and this data is also based on complex computer-based processing.

Climate Reanalysis Data

The development of climate and weather forecasting models has taken place over many decades and has truly been an international effort, driven by many academic and government research centers around the world. It has become an increasingly inter-disciplinary effort, given the nature of coupled models which rely on the work of scientists working across disciplines. In tandem with scientific developments, technology has allowed for increasingly greater data availability and coordination of data gathering and archiving efforts on an international scale[7].

An important international effort which started in the early 1990's has been the development of climate **reanalysis data-sets**. This effort was prompted by the challenges caused by data quality and consistency issues referred to in connection with data assimilation above, and the needs of the climate research community. While ongoing operational weather forecasting analyses are less impacted by changing data assimilation practices or changes in data sampling technology (and in fact, benefit from technological advances), climate researchers who are involved with running climate models over long historical periods (on the order of decades) are hampered by the inhomogeneity of data assimilation products. For example, climate researchers must be able to compare the results of recent climate modeling experiments with related modeling runs performed in the recent past. To do this, the simulation runs must be initialized and driven using a single consistent climatology record. Today, there exist many such reanalysis data-sets[8], typically spanning climatology over several decades (late 1940's to present), and new reanalysis data-sets continue to be developed. Each reanalysis attempts to utilize the best, state-of-the-art model and data assimilation resources available at a single point in time and for a particular type of application, which is then used to generate climatology using a single 'frozen' model configuration throughout the simulation run. Reanalyses are effectively meant to represent the 'gold standard' of climatology data-sets, tied to specific climate model/data assimilation configurations.

Reanalyses are a valuable resource to modelers and users of climate models in many ways. Given the availability of many different reanalysis data-sets, generated by a variety of climate mode configurations, they provide a valuable means of evaluating the similarities or differences across model output[9]. As will be discussed further, these reanalyses also provide a glimpse of the diversity of climate models and their configurations.

Climatology, Hindcasts and Forecasts

Having mentioned briefly the use of climate models to generate high-quality historical weather data (**climatology**) and the operational use of similar models to compute ongoing current and **forecast** meteorological conditions, there is actually a third state of climate simulation data called **hindcast** data.

Hindcast data generally represents simulations of recent weather conditions (less than a year past). This data is generated daily by operational weather forecasting models, and accumulates through time until it undergoes a quality control review and is incorporated within climatology data-sets – or is replaced by ongoing reanalysis exercises which catch-up to the time-frame of the hindcast data.

So, in essence, one can consider a continuum of available weather data: climatology (high-quality historical data), hindcast (current and recent weather conditions, not yet quality-controlled), and forecast data. Forecast data is eventually replaced by hindcast data as time goes by, which is itself eventually included or replaced by quality-controlled climatology data. Figure 5 depicts the relationship between the three data stages.

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[7] An engaging description of the evolution of climate modeling can be found in Edwards, P.N. 2010. *A Vast Machine: Computer Models, Climate Data, and the Politics of Global Warming*. MIT Press.

[8] See for example: http://www.reanalyses.org/

[9] A tool is available to compare reanalyses at: http://www.esrl.noaa.gov/psd/cgi-bin/data/testdap/timeseries.pl

Figure 5 - The progression of weather data vintages.

As mentioned earlier, the use of climate or numerical weather prediction models to generate backward-looking climatology is associated with different concerns than those encountered when using such models for forecasting activities. Data assimilation is important for both types of applications, however, it gives rise to different challenges. For long-term climatology simulation purposes, the quality of the initialization and boundary condition input data is very important and generally comes from reanalysis studies. Typically, these initial conditions are carefully controlled such that, over a certain simulation time-horizon, the climate model achieves certain equilibrium conditions which accurately characterize historical climate. On the other-hand, forecasting operations typically happen on a continuing basis. Operational models run by NOAA are typically run on six hour intervals, generating new forecasts on a six-hour basis. Given the near real-time operation of this forecasting activity, and the fact that the models can assimilate real-time weather data, forecast models are run differently. Instead of allowing the forecast model to run through a lengthy transition period to reach equilibrium, it is generally run on the basis of multiple initial conditions which generate a sample of forecasts. This 'ensemble' technique thus leads to an averaging of multiple forecast runs. This technique has many advantages, one of which is the fact that, to some extent, it reduces the sensitivity of the forecasting operation to real-time data assimilation challenges, such as data quality (e.g. an observational data-source becoming temporarily unavailable).

Model forecasts are typically probabilistic – in other words they provide a statistical picture of future weather. As with any forecast, forecast error typically increases with forecast horizon. There is significantly more uncertainty in a forecast of conditions several weeks or months into the future, compared to that associated with weather conditions only a few days into the future.

The Practical Challenges of Climate Modeling

The ecosystem of climate models, data assimilation systems and reanalysis data-sets continuously evolves, and all the while new global weather data becomes available and assimilated into research and development efforts. Climate modeling is a complex and highly-specialized activity which requires a deep familiarity with the underlying science, model internals, data sources and operational matters, as well as high-performance computing technology.

Looking at some of the 'mainstream' models developed by the research community in the U.S. (and pertinent to GP's modeling platform), such as the **Weather Research and Forecasting Model (WRF)**, the **Global Forecast System (GFS)** and the **Climate Forecast System Version 2 (CFSv2)**, it quickly becomes clear that these models are more appropriately viewed as classes of models, as any one model cannot be considered without taking into consideration its intended application, specific configuration details and most importantly, the associated data assimilation process used to initialize model simulations. All three above models are examples of coupled models incorporating sub-models describing specific geophysical components (atmosphere, ocean, land, sea-ice), which themselves can be configured in multiple ways depending on the focus of the researcher or forecaster. Furthermore, there exist dependencies across climate models, as the climatology generated by one model may be used to initialize or configure another.

Models 'ingest' and also generate very large amounts of data. If one considers a fine resolution, three-dimensional grid covering the surface of the model earth, with upwards of 50 or 60 cell layers stacked-up in the vertical component, it becomes clear that very large numbers of computations happen at every simulation time-step. If a climate model runs at a temporal resolution on the order of hours, and simulates years or decades of weather dynamics, this results in huge amounts of multidimensional data. Coupled-models simulate a wide range of physical processes, each with its own set of variables, and thus this multidimensional data potentially includes hundreds of variable time-series.

Data management and processing is a very important part of climate modeling. Over the years, academic research groups and other institutions (e.g. the World Meteorology Organization, WMO) have developed data standards to facilitate data communication, archiving and processing. This has resulted in a long list of specialized data formats such as GRIB, netCDF, BUFR and HDF.[10] Each of these file formats are specialized for certain types of data or application and climate modelers routinely need to process these various file type to either extract specific variables for further processing, or conversion into another data format.

It is useful to consider one specific climate model to get a glimpse of the complexity hidden within a single model, and also of the potential operation and data generation associated with a given model. This model is one of the many models that is currently being integrated with Enki's Morrigu™ platform and used by GP, however it is not the only model of interest.

The Second-generation Climate Forecast System (CFSV2)

The Climate Forecast System[11] (CFS) is a model representing the global interaction between Earth's oceans, land, and atmosphere. Produced by several dozen scientists under guidance from the National Centers for Environmental Prediction (NCEP), this model offers hourly data with a horizontal resolution down to one-half of a degree (approximately 56 km) around the earth for many variables. The second generation of this climate model (CFSV2) was launched in 2011.

CFSV2 is run operationally by NCEP, which is a group working within the National Weather Service (NWS), itself an agency of the National Oceanic and Atmospheric Administration (NOAA). CFSV2 can be configured to run over a wide range of time-scales and is considered a medium-range forecast model which can generate forecasts which range from weeks to months. NCEP runs this model on a daily basis, generating global forecasts over several time-frames and using different time-resolutions. Hence, CFSV2 is used both as a research climate simulation model as well as an operational forecasting model.

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[10] See for example https://climatedataguide.ucar.edu/climate-data-tools-and-analysis/common-climate-data-formats-overview

[11] An entry-point to CFSV2 information and data-sets can be found at https://www.ncdc.noaa.gov/data-access/model-data/model-datasets/climate-forecast-system-version2-cfsv2

Being a coupled model, CFSV2 consists of 4 sub-models all working in lock-step, as shown in table 1:

Table 1 - CFSV2 coupled models.

Component	Purpose
Global Forecast System (GFS)	Atmospheric Model (spectral, ~38km grid cells, 64 vertical pressure levels)
MOM4 Ocean	Ocean Model (~25km grid cells, 40 vertical levels)
NOAH Land Surface Model	Land Model (4 soil levels)
Sea Ice Model	Sea Ice Model

As with most operational climate and forecasting models operated or hosted by NOAA agencies, NCEP makes available a large range of model-specific data products via its numerous web-sites and the NOMADS distribution system[12]. The data-sets made available span a range of simulation runs: from daily operational forecast analyses, associated climate reanalysis data-sets, calibration data, to reforecast data-sets. Most of these data-sets are available under different spatial grid or temporal resolutions. Table 2: summarizes the data-sets available for CFSV2 and its predecessor, CFS.

[12] http://nomads.ncdc.noaa.gov/

Table 2: Summary of CFS and CFSV2 data-sets available from NOAA's National Center for Environmental Information (NCEI).[13]

Product Type	Number of Data-Sets
CFS Reanalysis Time Series & Monthly Means	2
CFS Reanalysis 6-Hourly Products	6
CFS Reanalysis Initial Conditions	3
CFS Reforecasts Time Series & Monthly Means	4
CFS Reforecasts "High-Priority" Subset	4
CFS Reforecasts 6-Hourly	6
CFSR Reanalysis Calibration Climatologies	5
CFSR Reforecast Calibration Climatologies	8
CFSV2 Operational Analysis	6
CFSV2 Operational Analysis 6-Hourly	5
CFSV2 Operational Analysis Initial Conditions	3
CFSV2 Operational Forecast Time Series & Monthly Means	2
CFSV2 Operational Forecast 6-Hourly Products	4

Table 2 gives us an idea of the diversity of data-sets of interest to climate modelers, as well as the volume of data generated. Most of the 58 data-sets (especially the reanalysis and reforecast data) cover decades of daily model runs (in simulation time), with at least one data file per simulation day. These data files are GRIB2 files, which are specifically designed to hold gridded data in binary form. Hence, each GRIB2 file contains data pertaining to the entire extent of the climate model's earth grid.

Running Climate Models in-House, or Using Published Climatology Data

Given the computational requirements for running climate model simulations and the complexity of identifying appropriate model configuration and initialization schemes, it would be sensible for a researcher to make use of published climatology or forecast data made available by NOAA as the starting point for further climate experiments or analyses. This essentially guarantees a certain level of data-quality, reduces the computational requirements, and generally speeds-up the research process. Of course, this is acceptable only if the application at-hand is compatible with the model configuration (resolution, simulation time-span) for which data is published by NOAA. Any application which, for one reason or another, requires a different model configuration or data at a different resolution than those published will require another strategy (e.g. setting-up the desired model configuration and running the model in-house), or a significant amount of data processing to, for example, downscale data to a different resolution.

[13] https://www.ncdc.noaa.gov/data-access/model-data/model-datasets/climate-forecast-system-version2-cfsv2

Furthermore, any model application which requires the initialization of a model such as the CFSV2, with a different reanalysis climatology, will also necessitate a substantial amount of data processing, or even in-house simulation runs. Such integration of models with third-party initialization or reanalysis data sets will also likely give rise to mismatching data formats, which will also require processing to bring data into one common format. Table 3 summarizes the challenges and complexities involved in making use of climate models.

Table 3: General climate modeling challenges: Data characteristics and model configurations.

Model/Data Characteristic	Challenge	Solution
Model grid resolution	Resolution must match the application requirements	Either run model at different resolution or process data (e.g. downscaling)
Simulation time-step (temporal resolution)	As above	As above
Model initialization	Does initialization data result in climatology that is consistent with application of interest?	Identify a more appropriate data-set for model initialization. This requires running model simulations to generate new climatology
Data coverage	Does published climatology data cover the historical period of interest?	Extend the climatology by running the climate model. This may lead to issues if having to use different data assimilation, or initialization data, which will require correction
Integrating multiple models or data-sources	Data format compatibility (from resolution issues to file format incompatibilities)	Data pre-processing to match data resolutions. Similarly, for data format issues

Data Requirements and the Morrigu™ Risk Hazard Platform

GlobalAgRisk's first generation of financial disaster risk management solutions covers a number of weather-driven natural hazards (temperature extremes, excess precipitation, extreme winds, soil moisture and drought) which are characterized on the basis of level 1 administrative units (first level of political boundaries within countries, such as states, provinces or administrative regions). This immediately imposes a set of conditions on the type of climatology data required for hazard quantification:

1. The data must have a spatial resolution at or below that of a specific countries level 1 administrative unit. Given that the spatial extent of administrative units varies considerably between countries, the most expedient and general requirement is to generate data at a spatial resolution that is higher than any countries' level 1 administrative unit spatial scale.

2. The climatology obtained must accurately represent the historical dynamics of each variable (or hazard) of interest. In other words, all hazard data should ideally be generated by a single climate model, and no variable should exhibit biases which call into question the statistical representation of the related hazard.

Enki Holding's Morrigu™ Risk Hazard Platform

Through earlier work with GlobalAgRisk Inc., Enki Holdings has demonstrated that its fourth generation risk hazard modeling platform, Morrigu™, provides a very powerful, yet flexible, modeling environment. Morrigu™ enables evaluation of hazard risk across a range of phenomena (weather-related risks such as extreme temperature, precipitation and wind, as well as earthquake risk). The emphasis in this document is on weather-related hazards.

Morrigu™ as a software and analysis platform

Morrigu™ is a unique environment: It represents a very open and modular framework which can integrate a variety of climate and other geophysical models. This is possible by virtue of the fact that Morrigu™ was developed with inter-operability in mind, and thus is equipped with a powerful set of data processing tools. This data-processing capability is really the 'glue' which enables Morrigu™ to host a variety of climate models and initialization data-sets, or alternatively, ingest published climatology data (similar to the CFSV2 data-sets published by NOAA) to drive other Morrigu™ analyses.

It is important to view Morrigu™ as an analysis environment or platform which integrates a variety of tools, models and data. This is its key strength and a significant advantage over any other risk hazard platforms.

In a sense, Morrigu™ is independent of any specific hazard model. It has an architecture which can accommodate alternative hazard model components: from proprietary hazard models developed in-house by Enki, to third-party hazard models developed by external research groups or agencies.

Morrigu™, for example, includes data-processing tools which enable the conversion of gridded climate data to different resolutions and different data formats. Because Morrigu™ was designed with hazard applications in mind, and therefore with downstream risk analysis and non-specialist clients, the platform also includes the capability to transform complex, gridded, climatology data to more user-friendly storage databases (specifically, SQL-based relational databases).

Figure 6 provides a conceptual view of Morrigu™ functionality. This representation emphasizes the different capabilities of the platform at a high-level, which does not reflect the software structure of the platform. In terms of software, the platform is made-up of many distinct software components developed at a more granular level than the one depicted in Figure 6.

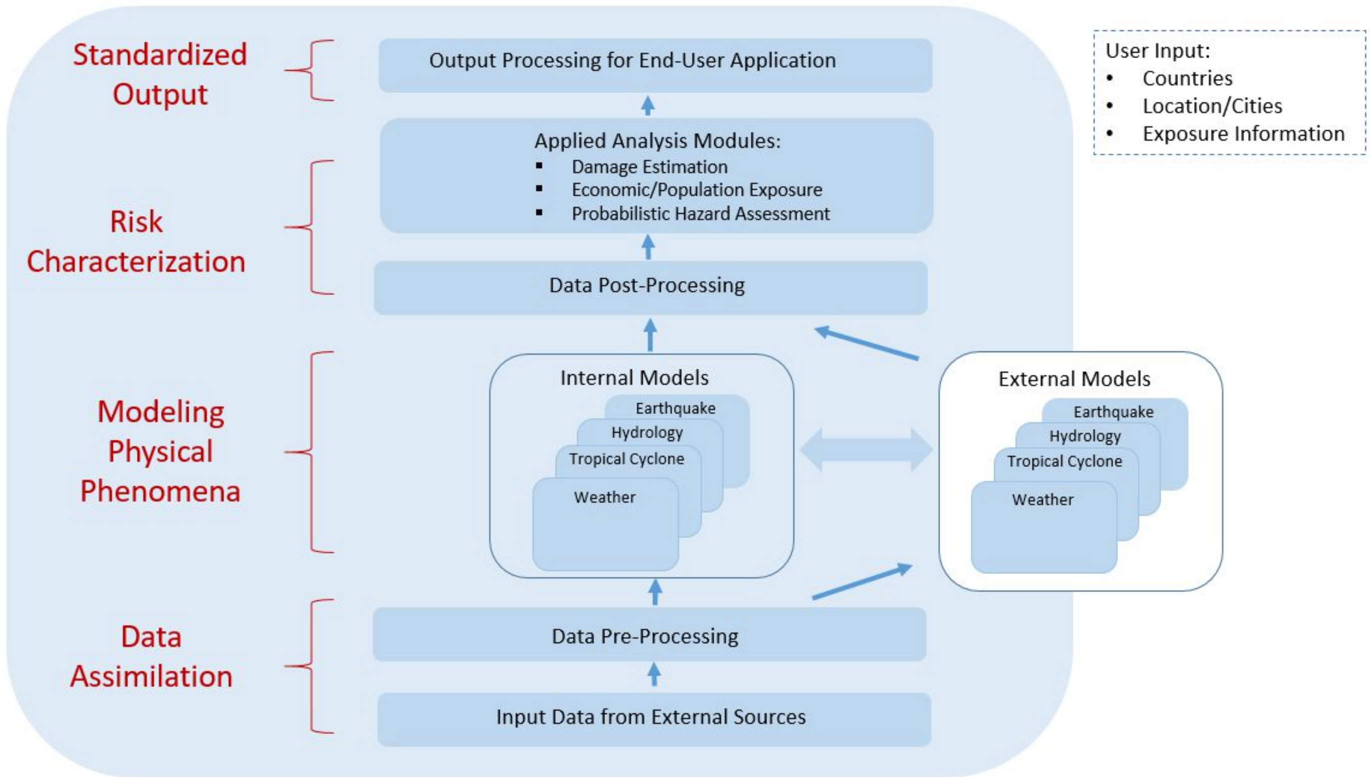

Figure 6 - Conceptual overview of the Morrigu™ risk hazard platform.

As figure 6 demonstrates, Morrigu™ is more than just one or more hazard modeling components, but a series of tools covering all aspects of hazard risk assessment. These tools were designed to manage the complicated and very time-consuming process of:

- acquiring and preparing input data,
- interfacing to and configuring hazard models,
- possibly integrating multiple hazard models (e.g. climate & hydrology) where one model's output serves as the other model's input,
- managing and transforming model output,
- feeding raw hazard model results through downstream analytical modules which
    - transform data to a statistical risk representation (e.g. using return periods)
    - merge hazard data with exposure information (e.g. economic and population exposure)
    - use exposure and hazard information to assess physical damage (buildings, crops), economic losses and potential loss of life
- finally, prepare output data in a format that is easily accessible by end-users.

A key aspect of Morrigu™ is the fact that it is able to leverage external hazard models, such as different publicly available climate models. This is significant in that it enable the use of well-known, peer-reviewed models and their associated data-sets (e.g. reanalyses) which have also undergone peer-review by the modeling community. This is made possible by the fact that Morrigu™ includes extensive software functionality which allows the interfacing of external and internal components, and which deal with the very time-consuming task of dealing with many different data-formats (such as the many types of gridded climate data formats mentioned earlier). Thus, much functionality is actually contained within the 'Data Pre-Processing' and 'Data Post-Processing' boxes of Figure 6. As is typical with many analytical or modeling exercises, data preparation and management is often the most time-consuming aspect of any study.

From a software-architecture perspective, Morrigu™ benefits from an approach reflecting the 'object-oriented' philosophy of developing software. Functionality is broken down into independent logical components which present a generic interface to the external world and other components. For example, a component which transforms raw hazard data into a statistical characterization (i.e. distribution) does not 'care' whether the data comes from a climate model, a hydrology model, or an earthquake model. This is very powerful as, for example, it facilitates the integration of further model types in the future. Morrigu™ thus represents a very flexible environment capable of adopting new hazard models in the future, as well as new data-sets.

Focusing back on climate models, one other important aspect of Morrigu™ resulting from its extensive data-processing capabilities, is the fact that it is capable of either running third-party climate models 'internally'[14], or alternatively, using already-generated simulation output made available through an external data-source (such as the CFSV2 reanalyses discussed in the previous section, made available by NOAA agencies). Either way, the above scenario is distinct from running an internal model, in the sense that it is not a third-party model, but a proprietary model developed by Enki and inherently part of the Morrigu™ environment. In Figure 6, a third-party model would sit in the 'External Models' box, while a proprietary model would sit in the 'Internal Models' box.

Reflecting back on some of the challenges in using climate models or their data products, it is clear that Morrigu™ offers an environment which is ideally-suited to solve many of the issues of data and model compatibility.

[14] In this case 'internally' signifies downloading the climate model software from its official (external) source, creating the environment within which to install it, then configuring the model. Once the model is ready, it can be interfaced to Morrigu™ components which control the simulation and manage data-exchange.

Annex D: Data Quality Assurance Process

This annex addresses a variety of issues related to data validation, quality assurance (QA), and verification of climate data and describes one of the QA processes used during the Rockefeller project.

Being many steps removed from the actual process of data generation, it is essential to 'sanity-check' the data before use, to identify any data problems which could result from any of the upstream data-generation and processing activities. Thus, when considering the various data checks that are possible, it is important to keep in mind how and where the data was initially generated, post-processed and thus where data quality issues may arise.

To clarify terminology, there are three different data checks possible with respect with model-generated data:

- Data Validation

Validation is the process used to determine whether a model (as implemented in software) generates the expected output. In other words, are there any logical programming errors which result in the output of the software model being different that the output that is intended. This could be the result incorrectly coding an algorithm which introduces an error in the computations. So, we might have a perfectly well-formulated model (e.g. a set of equations), but a poor implementation in software.

- Data Verification

Verification is concerned with making a determination as to whether model output accurately characterizes reality. So, in the case of climatology the question we have to ask is whether the historical weather simulated by the model accurately characterizes observed weather dynamics. If the model is developed to specifically model specific events, then the question is whether the simulated events accurately represent the observed events (note that climatology, generally speaking, represents average weather and as such is not meant to characterize discrete events in point and time).

- Quality Assurance (QA)

This is a very generic term and in the context of this project is used to identify quality issues with the climatological data received from Enki. It can best be thought of as a secondary level of validation and is concerned with identifying data issues which could result from either of:

  - Model inaccuracies (i.e. a data issue which should have been caught by an earlier verification process)
  - Model implementation issues (i.e. a data issue which should have been caught by an earlier validation process)
  - Data post-processing issues (i.e. a data quality issue introduced during the post-processing stage)
  - Data transmission problems, whereby a data download result in incomplete or corrupt data

Data quality (QA) assurance was performed on each of the 3,269 data series to identify missing data, suspicious data jumps or regime shifts, as well as any other pattern indicating potential problems in the data generating process. Both programmatic approaches and visualization can be used for different types of data QA. In this project, visualization was used to facilitate process by generating a panel of three different charts for each weather variable/administrative unit combination. Figure 1 provides an example of such pattern plotting for the soil moisture variable from Batdambang province, Cambodia.

Each panel provides three plots each providing a different view of the same data:

- **Top Plot**: A view of the complete daily time-series, showing trends and seasonal cycles (if any)
- **Bottom-Left Plot**: Simple histogram of daily data, showing the distribution of simulated weather values. Note that each of the seven variable typically displays a characteristic type of distribution.
- **Bottom-Right Plot**: A heat-map displaying weekly averages of the daily data. Each cell corresponds to a calendar week. As the color scale to the right of the heat-map shows, high values are expressed as increasingly dark red values, while lower values appear as light-colored red. Such heat-map is useful in identifying broad patterns, such as seasonality, as well as outliers.

The QA process was effective in identifying an issue near the beginning of the study which pointed to a problem with one of the input data sets feeding into CFS2. This problem was corrected and prompted a new cycle of data generation, which was also subject to the same QA process.

Note that this QA process can be viewed as a component of the broader data validation exercise, which is the confirmation that a model is correctly implemented into software code and thus generating expected results given a set of inputs.

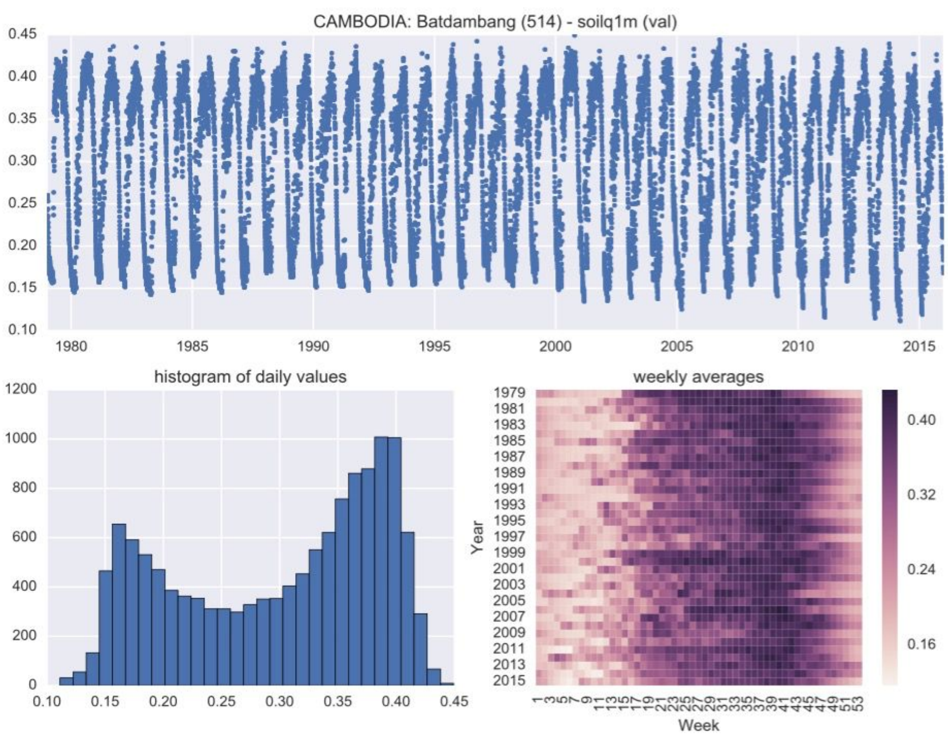

Figure 1 - Representative QA panel for soil moisture variable (Batdambang, Cambodia).

Annex E: Crop Calendar Index (CCI) Development

The crop bundle calendar was developed to identify when, over the course of a year, a given administrative unit is most vulnerable to extreme drought. The rationale is that drought vulnerability closely corresponds to the seasonal cropping calendar in developing countries, where most of the poor engage in agricultural employment. Since specific months every year expose farmers to more risk than others, a risk transfer product for extreme drought must take this into account.

In addition, a crop bundle calendar has applications for policymakers as a food security-planning tool. A drought in the middle of the primary farming season often leads to stunted yields or crop failures, both of which make farmers vulnerable to acute food insecurity and poverty. Understanding *where* and *when* crop production is vulnerable to extreme drought can help stakeholders make investments toward preparing and adapting for these conditions. This function is increasingly relevant due to climate change.

To determine which months are most exposed to drought risk, one first needs to know *which* crops are produced in the administrative unit and *how much* of each crop is produced in an average year. Then, for each crop, one needs to understand the different stages of the crop cycle: both *when* these stages occur and *how* each stage is impacted by drought.

To determine farmers' risk exposure by month, GlobalAgRisk completed the following steps for each administrative unit among our core group of countries:

1. Determine planting periods (if any) for each crop within a bundle of key global crops
2. For each crop, appraise drought vulnerability throughout the crop cycle and weight accordingly
3. Aggregate calendars for all crops using production weights

Once finalized, this process will facilitate the development of parametric drought risk transfer product for every administrative unit or aggregation of units around the world using monthly time periods that captured drought risk exposure.

Determine Planting Periods

Using several GIS data processing techniques, two publicly available datasets were transformed into aggregate planting calendars for 490 administrative units in 24 countries across Africa, Asia and South America. For an example of the end result, consider the Pailin administrative unit in Cambodia:

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.00	0.06	0.10	0.00	0.00	0.00	0.83	0.01	0.00	0.00	0.00	0.00

The value in each cell represents the percent of total crop production that is planted in the corresponding month. So, in Pailin, we estimate that 83% of total crop production is planted in July.

To come to this estimate, we identified a maximum bundle of 25 crops that were available in two unique datasets. The first dataset is United Nations Food and Agriculture Organization (FAO) Global Agro-Ecological Zone v4.0 (GAEZ) dataset (2000), which estimates the average sowing month for each crop, for years 1961-1990, that maximizes potential yield based on known data on climate, water availability, and land utilization type. GAEZ allows the user to select different parameters to access start day data, including water supply and input level for each crop. Given our area of interest is food security, we exclusively looked into rain-fed, low-input crops. Limiting ourselves to crops that have production data available through EarthStat, we selected 27 crops from GAEZ: barley, cabbage, carrot, chickpea, cotton, cowpea, groundnut, maize, foxtail millet, pearl millet, oat, onion, pigeonpea, rapeseed, rice (wetland/paddy), rye, sorghum, soybean, sugarbeet, sunflower, sweet potato, tobacco, tomato, wheat, white potato, greater yam, and white yam. The two millet and yam categories were later combined. From this data, we created a "crop calendar" that determined the proportion of each monthly start day within each administrative unit in 24 countries of interest for each of the 27 crops of interest.[1]

Consider the unique planting calendars for rice, maize, and soybeans in Pailin, Cambodia:

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Rice	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00
Maize	0.00	0.38	0.62	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Soybean	0.00	0.00	0.11	0.00	0.00	0.00	0.00	0.89	0.00	0.00	0.00	0.00

We interpret these GAEZ estimates as 100% of rice in Pailin is planted in July, 62% of maize is planted in March, and 89% of soybeans are planted in August. Note that each of these planting calendars sums to 1 (i.e., 100%). Identifying the primary planting period is the first big step to determining exposure to drought risk.

[1] Data were available through GAEZ in raster format at http://gaez.fao.org/Main.html#. Raster files are images made up of pixels or gridded cells and can be in multiple file types, such as .tif or .asc. Each pixel holds a certain value and/or color to comprise an image. In these GAEZ rasters, the world is organized into 5 arc-minute and 30 arc-second grids (roughly 0.091 degrees or 10 square kilometers), with each grid corresponding to a different start day value. While housing data in raster format is oftentimes desirable, it is not always ideal. Because of the curvature of the earth, these grids are not uniform in size across the entire surface of the world. Furthermore, many geoprocessing tools require that data be in the same format (raster-raster or vector-vector). Therefore, to make this data useable, it first needed to be converted from raster to vector formats through the QGIS polygonize tool. Once the raster file was polygonized, it then needed to be dissolved so that each start day value was merged or "dissolved" into a single polygon. This creates a shapefile of start days for the entire world in which each month has only one polygon.

After polygonizing and dissolving the start day shapefiles in QGIS, data processing was accomplished in the R language and environment. Shapefiles for crop start days and the country administrative regions were first converted to the same projection to ensure that they properly aligned. The two shapefiles were then intersected to create new polygons/attributes for each unique start day value within each admin region.

We used the newly intersected region polygons to calculate the areas of each start day within each administrative unit. Because we are only interested in start day values that actually exist, we removed all rows where DN (start day value) = 1, in which a value of 1 corresponds to "not suitable." Areas of each start day polygon within each administrative unit were then calculated. These areas (where DN != 1) were summed together to calculate the region totals so that we could divide each start day area by the total area to calculate the start day proportion. From these proportions, we scripted "if else" statements for each month of the year to run through every admin unit. If the start day value = 2 (January), 3 (February)..., then the start day proportion was returned. If the start day value didn't equal the month of interest, then 0 was returned. These values were then collapsed so that each administrative unit was left with one single row of values for January-December start day proportions. This process was repeated for all 27 GAEZ crops.

Appraise Drought Vulnerability throughout the Crop Cycle

In addition to the planting period, the crop flowering period and harvest period are also important times of year. In fact, according to FAO, the mid-season of a crop's growing cycle—which we refer to as the flowering period—is often when the crop's yield most readily responds to water input. Therefore, a shortage of rainfall or soil moisture during this critical time can lead to larger decreases in crop production.

To take crop cycle stages into account, we must first figure how many days comprise each stage of the crop cycle. While the length of crop cycle stages will vary by crop variety, agro-climatic conditions, and other factors, we looked for a source that provided average measures estimated in a consistent manner. The length of crop cycle stages in 23 crops of our bundle come from an report on water needs for irrigated farming issued by the FAO.[2] Estimates for rice[3] and tobacco[4] came from other sources. As with many of the variables in this model, these figures can be updated for future work.

For example, we estimated that 100% of rice is planted in July in Pailin, Cambodia. According to the source above, the average length of major crop stages of rice are:

	Crop Stages			
	Initial	**Development**	**Mid-season**	**Late**
Rice	20 days	45 days	55 days	15 days

While the planting calendars above are shown by months, it is clear that projecting out the rice growth cycle from the planting data requires going day by day. For now, we have decided to assume that the planting date for a crop occurs in the middle of the month—on the 15th. From there, we project out each stage of the cropping cycle. Thus, for rice in Pailin, we let the initial phase start on July 15th and last for 20 days, then we label the next 45 days as belonging to the development phase, and so on.

After projecting the different stages of each crop's unique cycle onto a daily calendar, the next step is matching each crop cycle stage to a value that assesses each crop's vulnerability to drought at that particular stage in its cycle. Again, we looked for a source that provided average measures estimated in a consistent manner that could be updated at a later date.

FAO estimates of a crop factor coefficient (Kc) that relates water requirements to a reference crop were used in this step.[5] These coefficients represent the crop's sensitivity to water shortages during a particular stage of the crop cycle. As stated previously, crops are most vulnerable to water shortages

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[2] Brouwer, C. and M. Heibloem, Irrigation Water Management Training Manual no. 3: Irrigation Water Needs (Rome: Food and Agricultural Organization, 1986), available from http://www.fao.org/docrep/s2022e/s2022e07.htm#chapter 3: crop water needs

[3] Heinemann, A.B.; Stone, L.F.; Silva, S.C. da. Arroz. In: Monteiro, J.E.B.A. (Ed.). Agrometeorologia dos cultivos: o fator meteorológico na produção agrícola. Brasília: Instituto Nacional de Meteorologia, 2009. p.63-79.

[4] FAO Water Development and Management Unit, Crop Water Information: Tobacco (Rome: FAO, 2015), available from http://www.fao.org/nr/water/cropinfo_tobacco.html

[5] Brouwer and Heibloem.

during the mid-season, when coefficients are often greater than 1. This is also true for the yield response factors for rice, shown below:

	Crop Stages			
	Initial	Development	Mid-season	Late
Rice	0.2	0.6	1.25	0.4

The crop factor coefficients were then used to weight drought vulnerability throughout the cropping cycle. In the coding, we multiplied the percentage of the crop being represented and the crop factor coefficient for that particular crop cycle phase in order to calculate a value for each day. While not the case for rice in Pailin, many crops were planted in several months, meaning that there are often overlapping cropping calendars with different crop factor coefficients. In our coding, these are all added together after the multiplication process to ensure their inclusion in the model. Finally, after a unique value of drought vulnerability is estimated for each day, these values were aggregated again to the monthly level.

The crop calendar now incorporates three crucial types of data in its metrics: 1) an estimate of when the crop is planted, 2) a projection of the crop's life cycle from the estimated planting date, and 3) values assigned to each phase of the crop's life cycle based on its crop factor coefficient to water needs. What remains is to aggregate these crop-specific values within each administrative region. However, all crops are not equally important to food production, so they cannot simply be summed to obtain an overall calendar.

Aggregate Using Production Weights

To integrate the relative importance of each crop to food production within the administrative unit, each crop's monthly drought vulnerability calendar is weighted by each crop's share of total production among the 25 crops in the food bundle. The data to accomplish this come from EarthStat, a joint effort between the University of Minnesota's Institute on the Environment and the University of British Columbia's Land Use and Global Environment Research Group. Among other data, EarthStat makes available area harvest and yield data for a wide variety of crops from the year 2000 that combines county, state, and national census statistics.[6] Since EarthStat collected subnational production statistics before relying on FAO national production statistics, these are likely the most accurate crop production estimates available for the administrative units. These production estimates were used to weight the relative importance of each planting calendar.

For example, consider the following calendars for rice and maize in Batdambang, Cambodia, which were created by aggregating the daily values of crop percentage and yield response factor (as described

[6] EarthStat also represents these data on a map (i.e., a raster file) in 5 arc-minute cells (roughly 10 square kilometers) across the world. For all 25 crops, GlobalAgRisk plotted the administrative units over the raster files for each of the 25 EarthStat crops and utilized the zonal.stats function from the SpatialEco R package. This function allowed us to compile all values for each admin unit. We then multiplied harvested area and yield in each grid cell to estimate production and then sum production within each administrative unit. Data available at http://www.earthstat.org/data-download/. Metadata available at http://www.earthstat.org/wp-content/uploads/METADATA_HarvestedAreaYield175Crops.pdf.

above). The rice calendar identifies October as the most vulnerable month, but the maize calendar identifies May and June. However, over 5 times as much rice is produced than maize. The large difference of production between the two crops suggests that they should not be weighted equally when summing drought exposure in the administrative unit.

Batdambang	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Prod (kt)
Rice	0.00	0.00	0.00	0.00	0.00	0.00	3.40	17.40	26.45	38.75	19.75	0.00	321
Maize	0.00	1.78	10.96	22.69	30.73	31.83	21.22	6.40	0.00	0.00	0.00	0.00	58

Therefore, the crop-specific calendars were multiplied by total production within the administrative region. This ensures that the most produced crops within an administrative unit are also the most important crops in our model. After multiplying by production, we then sum these values across all crops for each month. Here is the result for Batdambang, though it has been simplified to two crops instead of all 25 in the crop bundle.

Batdambang	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Rice	0	0	0	0	0	0	1091	5585	8490	12439	6340	0
Maize	0	103	636	1316	1782	1846	1231	371	0	0	0	0
OVERALL	0	103	636	1316	1782	1846	2322	5957	8490	12439	6340	0

As a final step, the overall calendar above is normalized. By doing so, each administrative unit acquires a standardized calendar that informs how agricultural exposure to drought risk is spread throughout the year.

Consider the calendar for Batdambang, now that the values have been normalized:

Batdambang	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
	.00	.00	.02	.03	.04	.04	.06	.14	.21	.30	.15	.00

Note that the shading matches that of the overall calendar above, but now the values are bit more discernable. We are interpreting the value of 0.30 in October by saying that the 30% of Batdambang's crop exposure to drought risk occurs in October. This is because October is a critical part of the cropping cycle for rice, which is the administrative unit's most important crop. Notice how the role of maize is still present but now reflects its share of production in the administrative unit.

The Pailin and Batdambang administrative units of Cambodia are easy examples because rice is so important there. However, this is the same basic process that is used to estimate planting calendars for every administrative unit in our core group of countries, using the maximum bundle of 25 crops. Additionally, the same process can work for every administrative unit in the world, given some time for the computation.

Annex F: Geo-Referencing Exposures for Financial Institutions

Not all loan books and current reporting are well organized or geo-referenced by any location other than the reporting branch office. In addition, the available loan book may contain artifacts that need to be cleaned from the data to provide the best representation of spatial lending exposure going forward, typically within the next 12 to 24 months. Two examples where careful and well-documented loan book cleaning may be necessary include:

- Where there has been substantial reorganization in lending or branch office structure, and
- Where there are discontinued lending programs in certain areas that have yet to mature or which otherwise remain on the books.

In these instances, selecting that portion of the loan book with a later maturity date will better capture the distribution of new and active lending. In addition, some defaulted and discontinued lending may remain on the books and, if systematic, should be purged for the purposes of establishing a portfolio-weighting index.

The remaining loan book is then allocated to active branch office locations and geo-coded based on existing spatial information or newly created spatial data for latitude and longitude and uploaded into GIS software and mapped (Figure 1). Using input from local branch managers, buffers can be drawn around each office to represent the operating range of branch loan officers, depicted as 50km in Figure 2. The buffers are then clipped to the country level administrative unit and the area remaining is calculated for each buffer, as in Figure 3. This is the total area assigned to the buffer. Next, the clipped buffers are intersected with the administrative units and a new area for the intersections is calculated. The area of intersection for each buffer is divided by the total area of the buffer to give an estimated proportion of each branch office lending by administrative unit. This proportion is multiplied by the portfolio assigned to a branch to give an estimated value for the lending in the intersected area. Finally, to obtain the proportion of the total lending portfolio within each administrative unit, the values of each intersected area are summed by the administrative number assigned during the intersection step.

Figure 1 - Example of geo-coded and mapped branch office locations.

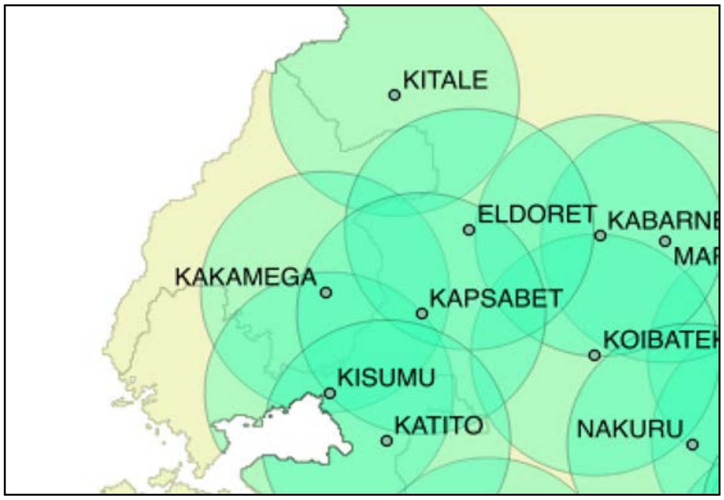

Figure 22 - Operating range buffers drawn around each branch office location and clipped to the country level administrative unit.

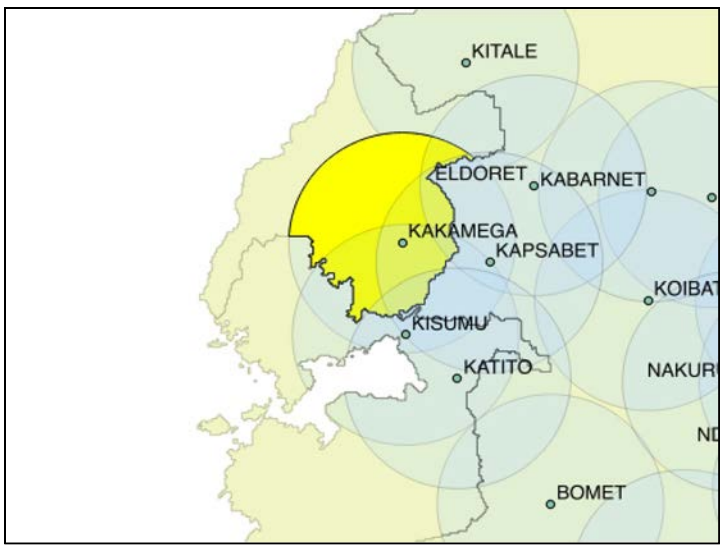

Figure 3 - Buffers are intersected by administrative unit and a second area calculation is made.

Annex G: Advanced Statistical Methods for Return Period Analysis

A Comparison of Return Period Calculations Using Empirical, Fitted Distributions, and Tail Corrected Distributions *

Michael Shaw, Ph.D.
GlobalAgRisk

1 Introduction

The probability of an event occurring is of great interest in risk management and the probability of event is often expressed as the expected time in years between the reoccurrence of the event. An event with a return period of 100 years means that the probability of that event occurring in any one year is 1/100. The data in this report are measurements of a yearly soil moisture index and the event is defined as the soil moisture being a certain value or less. Of interest are extreme events when soil moisture levels are low (droughts). The data represent 37 years of measurements taken from 24 countries. The problem at hand is to determine what measurements will constitute an extreme event, i.e. a 100-year event, from 37 years of data. One way of estimating probabilities of events is to order the measurements. The smallest measurement of 37 years occurs only once and can therefore be thought of as having a 37 year return period. The second smallest measurement represents an event that contains that measurement and any other measurement less than the said measurement (two points) and so has a return period of 37/2 or about 18 years. Spreadsheet percentile functions like those available in Microsoft Excel or LibreOffice, and programming environments like R[1] basically use this technique to determine return periods. Section 1 of this report shows the limitations of this technique by using the soil moisture data as an example. One problem with computing return periods this way is that a 100-year event is not represented by any value in a data set with 37 values as at least 100 values would be needed to have that 100-year event. If the data set contains many more years of observations, then ordering the data agrees more with common experience. The smallest measurement taken over 200 years can be more reasonably thought of as a 200-year event. Techniques used in section 2 provide a parital solution to the

*This report is exploratory in nature and the results presented should not be used to make any financial decisions. It is intended to provide a basis for further investigation and should be used for educational purposes only.

limitations of ordering a small data set to determine return periods by replacing the 37 year data set with a data set containing many more measurements (in fact an infinity of measurements) that closely resembles the original data set. There are many replacement sets called distributions that have been proposed by researchers in the field of statistics[2] and the problem becomes choosing the distribution that best represents the properties of the original data. A distribution is described by a mathematical formula that allows the calculation of return periods outside the range of the original data, and can be used to determined how well the distribution matches the original data. Distributions are grouped in families based on the type of mathematical formula that discribes them. Whithin each family distributions are distinguished form each other by a set of parameters. To determine which distribution best represents the data set, optimization methods are used to select the set of parameters that specify the distribution. For this report three families of distributions were selected, the Weibull, normal, and lognormal families and four optimization methods, maximum likelyhood (mle), quantile matching (qme), goodness-of-fit (mge) and moment matching (mme) are used[5]. The function fitdist() in R can be used to fit a distribution to a data set using one of the optimization methods. There are limitations of this technique though that many different distributions may represent the original data well but while they may produce the return periods for values near the range of the original the data set, they can have different values when calculating return periods for extreme event out side the range of the 37 data points. Each distribution may give a different value for a 100- or 200-year events for example. Having different distributions produce different return periods for the same data set throws into doubt the validity of the return period calculations. The example in Section 2 demonstrates this issue.

For this report a heuristic measure of how well a distribution fits the data set is determined by counting the number of times an event is observed in the original data set. For example the value of a 100-year event is calculated for each country. Since there are 24 countries and 37 years, under the assumption of independence of events between countries and years it can be expected, there should be (24)(37)/100 or about 9 occurrences. Whether an event occurs or not is a random variable with expected value of np occurrences and a standard deviation of $\sqrt{np(1-p)}$ where n is the size of the set and p is the probability of the occurrence of the event[1]. A distribution should reasonably produce a value within 2 standard deviations of the expected value. For a 100-year event over 24 countries and 37 years, reasonable distribution should produce from 3 to 12 observations in the original data.

Section 4 applies a technique that partially solves the problem of distributions not agreeing on the return periods for extreme events. This technique has been developed recently by many investigators[3][5][4][6]. and is a hybrid of the techniques for sections 1 and 2. In this report instead of calculating return periods from a fixed selected distributions, we represent the original data with a large but finite table of values, 10,000 for this example. Table 4 is produced

[1] See the binomial distribution in[2]

by first fitting a distribution to the data and applying a process to a specially selected large set of values from the distribution that adjusts the values within a small range of the lowest and highest values of the selected values. Return periods are then calculated on the new values by an ordering technique as discribed previously on the large set of 10,000 values. Details are given in section 4 along with R code.

2 Return period calculation using empirical quan tiles

In this section, return periods are calculated from the data by using the percentile function form Microsoft Excel (MS), the percentile function from libreOffice ODS (LO), the quantiles calculated from the empirical distribution from R (R.ecdf), and the quantile function from R (R.quantile). Table 1 shows the data from three countries sorted from smallest to largest for the first few data points with return periods calculated by using the above functions, rounded to the nearest year. Infinity is represented by Inf.

Country	year	csmi	MS	LO	R.ecdf	R.quantile
ARMENIA	2000	0.161690	100	Inf	37	Inf
ARMENIA	2001	0.179136	36	36	19	36
ARMENIA	1999	0.180088	18	18	12	18
ARMENIA	1989	0.181466	12	12	9	12
ARMENIA	2006	0.189131	9	9	7	9
ARMENIA	1995	0.190262	7	7	6	7
BOLIVIA	1986	0.209389	100	Inf	37	Inf
BOLIVIA	1985	0.209510	36	36	19	36
BOLIVIA	1993	0.212529	18	18	12	18
BOLIVIA	1983	0.216447	12	12	9	12
BOLIVIA	1994	0.216694	9	9	7	9
BOLIVIA	2010	0.217173	7	7	6	7
BURMA	1999	0.256499	100	Inf	37	Inf
BURMA	1979	0.329808	36	36	19	36
BURMA	2005	0.334781	18	18	12	18
BURMA	2004	0.359761	12	12	9	12
BURMA	2006	0.360782	9	9	7	9
BURMA	2014	0.362370	7	7	6	7

Table 1: Return periods calculated from empirical functions

This table reveals the problem encountered when using quantiles on discrete data to calculation return periods. Note that the return periods repeat for different countries. It is highly unlikely that all countries would have exactly the same return periods for their data. Consultation of the user manual for MS percentile functions shows that for discrete data, each data point other than the smallest is assigned as a quantile the value of a multiple $m-1$ of $1/(n-1)$ where n is the number of data points and m is the position of the point in the ordered data. So for example if there are 37 data points, the second smallest point is assigned the probability of 1/36 for a return period of 36 years. The third smallest data point is assigned a probability of 2/36 for a return period of 18 years. LO, R.ccdf, and R.quant use a similar scheme and the smallest data point is interpolated slightly differently for each. The return periods then are not functions of the actual data points but of only the number of points and the position they appear in the order data. Since all data sets have the same number of points, all will have exactly the same return periods. Thus using the quantile functions on a discrete set of points to determine return periods is of very little, if any, value. The discussions in the next sections provide a more realistic way over determining event probabilities

3 Calculation of the 100-year return value using fitted continuous distributions.

In this section, the mean weekly soil moisture from each country is fitted with the distributions from the Normal (norm), Lognormal (lognorm), and Weibull (weibull) family of distribution. The optimizations used to determine the parameters specifying the specific distribution in each family of distributions were the maximum likelihood estimation (mle), moment matching estimation (mme), quantile matching estimation (qme), and maximum goodness-of-fit estimation (mge). The parameters for the distributions were determined using the R function fitdist() from the package fitdistrplus. The corresponding 100-year (.01 quantile) value was calculated for each fit. The value of the quantile was then compared to the original data. The number of values in the data less then the calculated value corresponds to the number of occurrences of a 100 year or more event. Table 2 shows the number of the occurrences for each fitted distribution and optimization technique. A heuristic way to determine if a technique is realistic to consider the occurrence of an event as being binomially distributed[5] where the event has occurred or has not. For example, a 100-year event (probability 0.1) would occur in 24 countries over 37 years on average $24{*}37{*}0.01 = 8.88$ times with a standard deviation of $\sqrt{24 * 37 * .01 * .99} = 2.92$. If the number of occurrences is different from the expected value of about 9 occurrences by more than two standard deviations, it could be considered as not valid. No confidence intervals are presented in this report but they are the subject of ongoing investigation.

Table 3 displays the approximate number of occurrences expected to happen for each return period in years for 24 countries and 37 years.

	10	20	50	100	200
norm	79	48	17	8	5
norm.mge	83	43	15	5	0
norm.qme	96	62	35	24	10
norm.mme	79	48	17	8	5
lnorm	83	55	24	13	8
lnorm.mge	80	43	15	8	0
lnorm.qme	96	62	35	24	11
lnorm.mme	83	56	25	14	8
weibull	55	21	7	2	1
weibull.mge	86	41	8	2	0
weibull.qme	96	65	38	24	7

Table 2: Number of calculated occurrences of a 100 (or more) events from 24 countries over 37 years

	10	20	50	100	200
expected	89	44	18	9	4

Table 3: Approximate expected number of occurrences of an event from 24 countries over 37 years

4 Return period calculation using non parametrically fitted distributions

In this section a technique that uses a nonparametric kernel smoother on a parametrical fitted distribution is used to calculate return periods. The details of kernel smoothing are complicated and are given in section 5.

The process of fitting non parametrically kernel smoothed distribution requires the inverse functions and derivatives of inverse functions to get a final smoothed density. Of the normal, lognormal, and Weibull distributions, only the Weibull distribution has a closed mathematical form allowing calculation of inverses and derivatives. Lognorm and normal distributions require numeric integration and differentiation. Development of the process using lognorm and normal distributions is ongoing.

The data were first fit with a Weibull distribution using an mge optimization method. The data is then transformed onto the interval [0.1] using the fitted distribution. The transformed data set is theoretically uniformly distributed but in practice is processed with a kernel smoother to make the tranformed data have uniform properties. Kernel smoothers tend to distort the extreme values of the data so a tail-correcting technique is applied to the kernel smoothed data. To obtain quantiles, the tail-smoothed data is transformed back to original domain of the empirical data. The tail-correction functions and inverse transforms are not available as functions or packages in R but were written using the R language. The intermediate steps of this process are illustrated in the section

”Details and Figures” at the end of the report.

Table 4 compares the number of occurrences for various return periods for the Weibull and tail-corrected Weibull distribution (Weibull.t.c). Some improvement in the extreme return periods is noted justifying further investigation with other distributions.

	10	20	50	100	200
Weibull	86	41	8	2	0
Weibull.t.c	101	43	9	4	1

Table 4: The number of occurrences for each return period.

5 Conclusion

This report is meant to give a realistic determination of return periods of critical events. The calculations are made using theoretical models, empirical functions, and a reasonable expected value to the number of occurrences of events was used to determine a heuristic goodness of fit. Various theoretical values are compared to empirical calculations. It was demonstrated in this praper that theoretical distribution determine occurrences of events. that tail correction can improve the fit with the Weibull distribution, and that empirical quantile functions are of little use. A rigorous mathematical examination of confidence intervals and the use of other distribution families is ongoing.

6 Details and Figures

6.1 Example of kernel smoother with boundary correction

This section illustrates the combination of parametric and nonparametric distribution fitting to empirical data.

First a parametric family of distributions is chosen and the parameters are determined by an optimization scheme. In this example the soil moisture data were fit with a Weibull distribution using mge optimization technique. Let $F(x)$ represent the fitted distribution and $\{x_i\}$ the data points. The data points are transformed to a data set $\{y_i\} = F(x_i)$. The resulting data set is theoretically uniformly distributed. The transformed data set, being not quite uniform, is smoothed using a typical kernel-smoothing technique. In this example the R function density() with the Epanechnikov kernel was used. The tail correction was then applied to the kernel-smoothed data. No R functions are available to do this, so a tail correction application had to be written in the R language. Figure 1 shows the transformed data histogram, the kernel-smoothed distribution, and the tail-corrected kernel-smoothed distribution.

Once the transformed distribution is tail corrected, it is transformed back using an inverse transform. The inverse transform is also not available as an R function and had to be written independently. Figure 2 shows the original data histogram together with the fitted parametric density and the tail-corrected density function.

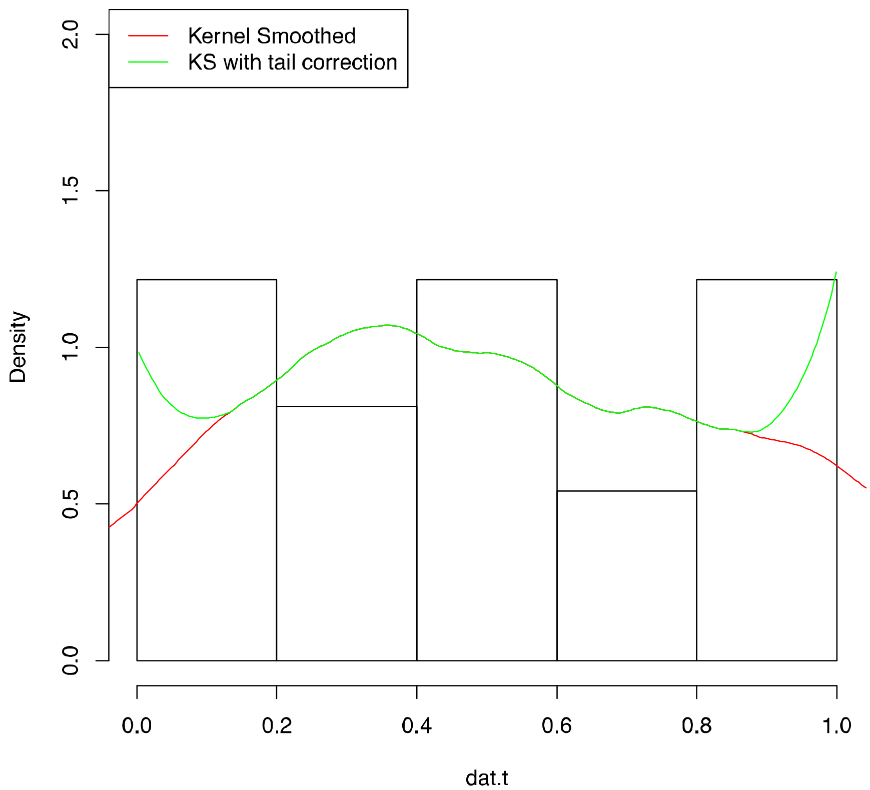

Figure 1: Histogram of the transformed data, kernel-smoothed density, and tail-corrected density

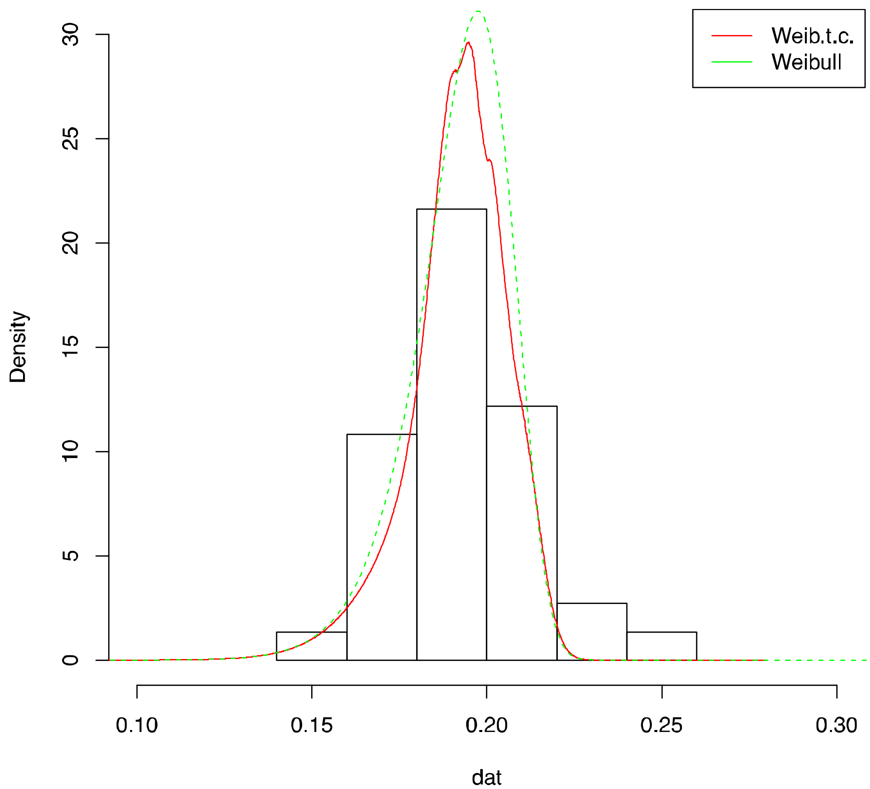

Figure 2: Histogram of the original data, Weibull fitted density, and Weibull tail-corrected density (Weib.t.c)

6.2 R code

The kernel smoother

$$f_{trans}(y) = \frac{1}{nh}\sum_{i=1}^{n} K\left(\frac{y - Y_i}{h}\right)$$

is implemented in R by using the R function density() with the kernel option set "epanechnikov". h is estimated by density() using the default estimator. Y_i is the data value X_i transformed by $Y_i = T(X_i)$ and T is the fitted Weibull curve to the original data with parameters deterimined by the R function fitdist(). n is the number of data points.

$$f_{trans}(y)$$

is tail-corrected by

$$f_{trans}(y) = \frac{f_{trans}(y)}{k_y}$$

where

$$k(y) = \int_{max(-1,-y/b}^{min(1,(1-y/b)} K(u)du$$

and $x = ch$ for $0 \leq c \leq 1$. k_y is calculated with the R code

```
>tc<-function(x,h){
>   v<-rep(0,length(x))
>   for(i in 1:length(x)){
>      l=max(-1,-x[i]/h)
>      u=min(1,(1-x[i])/h)
> # the analytic derivative of the Epanechnikov kernel
>      v[i] <- 3/4*u-1/4*u^3+1/2-
>                   (3/4*l-1/4*l^3+1/2)
>   }
>   v
>}
```

The distribution is transformed back to the original domain by

$$f(x) = \frac{f_{trans}\left(T(x)\right)}{\left|\left(T^{-1}\right)'\left(T(x)\right)\right|}$$

where $\left(T^{-1}\right)'$ is the derivative of the inverse Weibull, which is analytically calculated and implemented in R by

```
> # Inverse Weibull function
>pweib.inv<-function(x,sh,sc){
>   sc*(-log(1-x))^(1/sh)
>}

># Inverse Weibull derivative
>pweib.inv.der<-function(x,sh,sc){
>   (sc/sh)*(-log(1-x))^(1/sh-1)*1/(1-x)
>}
```

References

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[3] M. P. Wand, J.S. Marron and D. Ruppert [*Transformations in Density Estimation.*] Journal of the American Statistical Association, Vol 86, No. 411(Jun., 1991), pp.343-353

[4] M.C. Jones [*Simple boundary correction for kernel density estimation.*] Statistics and Computing, 3,1993, p. 135-146

[5] R.J. Karunamuni and T. Alberts [*A locally adaptive transformation method of boundary correction in kernel density estimation.*] Journal of Statistical Planning and Inference, 136, 2936-2960

[6] Tine Buch-Larsen, Jens Perch Nielsen, Montserrat Guillen and Catalina Bolance [*Kernel density estimation for heavy-tailed distributions using the champernowne transformation.*] Statistics, Vol. 39, No. 6, December 2005, 503–518

Annex H: Portfolio Modeling Methodology

The results presented in sections 8 and 9 have been generated using individual portfolio models, which share a common structure, adapted to the financial instruments and questions specific to the two scenarios considered: an FDRM system for a MFI network (section 8), and emergency liquidity offerings (ELO) for MFIs from a fund managed by a Microfinance Investment Manager (section 9).

Model Inputs

A view of excess rainfall, severe wind, and drought risk from 1979 to 2015 form the inputs to the model. These are generated as described under section 7, using the outputs of the Morrigu™ platform. From these views of risk, the portfolio model inputs comprise an aggregate index value for each peril, year and institution that represents a geographic weighted view of severity at the institution level.[1]

Two sets of aggregate index values are applied (again differentiated by peril, year and institution) within the portfolio models:

1) As the basis of the calculations underpinning the **credit response** for both the MFI network and the ELO fund, the index values are determined based on a selected return period threshold (i.e. 1-in-5, 1-in-7 or 1-in-15 years in this analysis).[2] This resulting index value gives a view of a 'drawdown' or 'payout' rate for the contingent credit instruments per institution, year and peril (**credit drawdown rate**);
2) As the basis of the calculations underpinning the **capital response** for the MFI network, the index values are determined based on a selected return period threshold (i.e. 1-in-10 or 1-in-25 years in this analysis)[3]. This resulting index value gives a view of a 'payout' rate for the capital response (and the risk transfer product) per institution, year and peril (**capital payout rate**).

The application of the different return period thresholds allows the credit response to begin for lower severity events than the capital response. The credit response instruments are therefore triggered at a higher frequency.

The portfolio models compute the key presented statistics through the application of the risk transfer product and credit/ELO financial structures alongside key 'financial information' (as defined below) onto two views of event occurrence;

- The historical time series from 1979-2015;
- A Monte Carlo simulation of 1,000 draws of the aggregate national index value for each peril and country (or MFI) combination, with adjustments to the resulting stochastic catalogue to account for extreme events like El Niño which produce globally correlated natural disaster conditions.

[1] Note that for the MFI network, a single institution per country is modeled, whereas for section 9 – the emergency liquidity offering fund – multiple institutions per country are modeled.
[2] In this analysis for extreme wind and rain, the return period threshold is applied at the administrative unit level, whereas for drought it is applied at the country.
[3] In this analysis for extreme wind and rain, the return period threshold is applied at the administrative unit level, whereas for drought it is applied at the country.

Financial structures

MFI Network

For the MFI Network, the financial product responses to differing severity levels are detailed below. In all cases, the instruments are responding to a modelled view of credit or capital needs, based on the indices described above. As drought products are structured differently than extreme rain and wind products, they are broken out into two subsections that follow.

Extreme Wind and Rain Products

FDRM System Credit Response for an Institution and Event

{Credit drawdown rate (0%-100%) based on the aggregate country index} x {Limit of credit provision (10% of lending portfolio)}

A franchise deductible of 20% is applied to reduce the frequency of the payout mechanism. The product users have the ability to then decide if they will cover the deductible funding need internally or not. In the current analysis, it is assumed that the MFIs only receive credit funding as paid out by the credit product itself, so deductibles are effectively not charged through the system. As noted elsewhere in this report, future work will look to develop new product structures wherein a country level return period (rather than administrative unit level) can be applied as means for determining payouts.

FDRM System Capital Response for an Institution and Event

A step function is applied to the assessment of capital needs captured in the modelled 'capital payout rate'. There is a long precedent of using step functions in the insurance industry to simplify the terms of payout from products[4] and to speed the response of the product. As detailed above, the limit of capital provision is 5% of the lending portfolio of the institution and the limit of credit provision is 15%, where in it is assumed that a third of this credit is sourced locally by the MFI and the remaining two thirds are provided by the DRF and external credit providers sourced by the DRF. The terms applied are as follows:

[4] See Mahul and White, Earthquake Risk Insurance, Sendai Series, World Bank, 2012

if	Capital payout rate > 50%
	Capital response =
then	**100% x limit of capital provision**
if	Capital payout rate > 40% and < 50%
	Capital response =
then	**60% x limit of capital provision**
if	Capital payout rate > 30% and < 40%
	Capital response =
then	**40% x limit of capital provision**
if	Capital payout rate > 20% and < 30%
	Capital response =
then	**20% x limit of capital provision**
if	Capital payout rate < 20%
then	**No capital response occurs**

Figure 1 – FDRM step function depiction, extreme precipitation and windspeed.

Financial Instruments at the Global Level

See section 8 for details of how the financial instruments operating at the global level respond.

Drought Products

FDRM System Credit Response for an Institution and Event

Credit drawdown rate (0%-100%) based on the country level return period x Limit of credit provision (10% of lending portfolio).

FDRM System Capital Response for an Institution and Event

Similar to the extreme wind and rain products, a step function is applied to the drought product. In this case, however, the thresholds are set by the event return period (rather than the assessed capital payout rate). The terms applied are as follows.[5]

[5] The step function for capital response for the Cambodia MFI in this analysis has been adjusted to be more of catastrophic cover such that the attachment point is a 1-in-25 year event corresponding to a 40% payout. The exhaustion point is consistent with the table below at 1-in-50 year event and there are no other thresholds used in between the attachment and exhaustion point.

if	Event return period > 1-in-50 years
	Capital response =
then	**100% x limit of capital provision**
if	Event return period > 1-in-25 years and < 1-in-50 years
	Capital response =
then	**60% x limit of capital provision**
if	Event return period > 1-in-15 years and < 1-in-25 years
	Capital response =
then	**40% x limit of capital provision**
if	Event return period > 1-in-10 years and < 1-in-15 years
	Capital response =
then	**20% x limit of capital provision**
if	Event return period < 1-in-10 years
then	**No capital response occurs**

Figure 2 - FDRM step function depiction, drought.

Financial Instruments at the Global Level

See section 8 for details of how the financial instruments operating at the global level respond.

Microfinance Investment Vehicle – ELO Fund

For the emergency liquidity offering, the financial product responses to differing severity levels are as follows:

Credit Response for an Institution and Event

The terms of access to the credit facility will be determined in an agreement between the MFI and the fund. A step function has been applied to ELO access, to simplify and ensure speed of liquidity provision, and to reduce the administrative burden (and associated costs) to the fund. The terms are below, note that the limit of the ELO facility will be specific to each MFI for implementation – for the purposes of the modeling herein, the limits are $5 million for each MFI, for each modeled peril (severe wind, excess rainfall, drought).

Figure 3 – FDRM credit response for a microfinance investment vehicle.

Capital Response for an Institution and Event

No capital response has been modeled at this stage. However, as noted under section 9, a capital response alongside the ELO facility should be considered to deal with scenarios where the institution finds its balance sheet impaired post-disaster, and cannot draw down from the ELO facility without breaching regulatory requirements on capital adequacy, or loan covenants.

Exposure Management at the Fund Level

See section 9 for details of the financial instruments used to manage the contingent liability to MFIs out of the ELO fund.

Portfolio Modeling Methodology

For the MFI network, the stochastic catalogue of 1,000 draws produces the primary outputs at the portfolio level, based on the above-described input data and assumptions. The model considers inflows and outflows to the Disaster Recovery Fund (DRF) under each of the 1,000 disaster occurrence scenarios, and outputs an estimate of the access fee that would need to be charged to subscribing MFIs to maintain a cost neutral system (and as part of this, to maintain the target balance of the DRF, which is modeled at $3mn). The inflows and outflows that are captured, are detailed in the assumptions table below. The stochastic catalogue is also used to simulate credit and capital drawdowns by MFIs from the DRF, and from this, the following determinations can be made: the amount and cost of external contingent credit that would need to be arranged; the target balance of the DRF; and the amount and cost of risk transfer products needed to support capital needs.

For the country-level modeling a time-series of 10 years is used, with the MFI's financial information providing the starting conditions, and 1,000-draw stochastic catalogues modeled for each of the 10 years, to provide a view of event occurrence over this time horizon. The impact of this 10-year series of modelled event occurrence on the balance sheet of the MFI is modelled, both with and without the

FDRM system in place. The assumptions that shape the modelling are detailed in the assumptions table below. Both the portfolio, and country-level models show how the FDRM system would have performed if applied onto the event occurrence data from 1979 – 2015.

The ELO fund portfolio model has a similar structure to the MFI network portfolio model, applying a 1,000-draw stochastic catalogue of disaster occurrence to a hypothetical portfolio of MFIs. From this simulation of ELO drawdowns from the fund, the financing that needs to be in place to support the ELO contingent liabilities (in this case the risk transfer product, and credit lines), and the cost of these financing sources are modeled. The model also provides a view of an evolving portfolio using the 1979-2015 time-series of historical event occurrence. This view assumes that at inception (year 1 – 1979 event occurrence), the ELO fund subscriptions amount to 40% of the 'mature' portfolio modeled for the full stochastic simulation. This portfolio is allowed to grow at 12% a year. The inflows and outflows to the ELO fund based on the 1975-2015 hazard time-series, and the growing portfolio are then modeled, with the excess of loss risk transfer product providing a backstop. The resulting performance of the fund is output. The table below detailing assumptions gives the details of the parameters determining inflows and outflows to the fund.

Assumptions/financial Information

This section details the key financial information feeding into the model:

Table 1 - Model assumptions.

Assumption	Notes
MFI network portfolio model	
Projected long term portfolio growth rate for MFIs = 15%	Generic assumption drawn from industry data/discussions with VFI. Factored into modeling of cost of system overall. This is applied at the multi-country portfolio level. Individual country models have also been prepared, with individual portfolio growth rates specific to the country environment (as used to derive results for Cambodia, in section 5).
Target return on capital invested in the DRF = 10%	Generic assumption drawn from industry data/discussions with VFI based on the expectation that capital invested in the DRF would require an annual return.
Cushion for DRF size and total credit needs assessment = 25%	The required size of the DRF is set using maximum modeled drawdowns to meet response needs of the subscribing MFIs. A cushion of 25% on top of this maximum number is applied when determining the target net assets of the fund. The same cushion is applied when estimating the maximum amount of external contingent credit lines needed to support the response for the worst case scenarios.
Average interest on treasury management of DRF = 0.5%	Drawn from the current low interest environment. This number shows up as income into the DRF in the simulation.

Average interest rate on contingent credit from DRF to MFIs = 10%	This assumption is based on discussions with VFI about feasible ranges of interest for the hypothetical network. It is likely to change substantially through advanced product discussions with MFIs as part of implementation. It is modeled as an inflow to the DRF in the simulation.
Cost of contingent credit from external providers = 8%	85% of the credit needs are modeled as met by external contingent credit providers. An assumption of a 10% interest rate is applied to these external facilities, and this is modeled as an outflow from the DRF.
Cost of risk transfer product from GP	The cost of the risk transfer product is modeled based on the total FDRM sum-insured required to support the system and as % of the total loan portfolio. The cost of the product is taken as a multiple of the aggregate modeled expected losses to the risk transfer contracts.
Commitment fee on available contingent credit in facility = 0.5%	The model assumes that a fee of 0.50% of the available credit through the external contingent credit facilities is charged annually as part of the facility arrangement. This number is a placeholder until product discussions advance further.
Cost of non-performing loans out of DRF = 1%	This is modeled as an outflow from the DRF in the simulation.
DRF operating costs = $500,000	This covers the cost of the DRF facility management, and is exclusive of cost of capital.
Average term of recovery loans = 12 months	This is taken into account when modeling the inflows and outflows to the DRF
Average size of recovery loans = $225	This is used for the country-level model presented herein for Cambodia
Percentage of recovery lending that becomes permanently absorbed into portfolio = 10%	This is used when modeling portfolio growth in the simulation at the country level
MFI capacity to offer recovery lending without FDRM system in place = 25% of total targeted response	For the modeling of the counter-factual to the FDRM system, it is assumed that MFIs can meet some part of the recovery lending need without the FDRM system to support them
Additional capital erosion without recovery lending = x2	Recovery lending is modeled as a protective factor, reducing capital erosion for MFIs by financially empowering their client base and supplementing this with additional loans. Evidence from post-disaster recovery lending programs supports this concept as described in the main body of this report.
Other financials specific to country environments	Additional financial information has been applied in the country-level modeling, that is specific to each country environment. This includes:

- Target operating margins for MFIs
- Target portfolio growth rates
- Targets for debt to equity ratios

ELO fund portfolio model	
Projected annual growth of ELO portfolio for the fund = 12%	This number is used to model the potential evolution of the fund portfolio of contingent credit facilities using the 1979-2015 time series of hazard data.
Cost of capital to the fund, required to support ELO lending = 3%	This is modeled as an outflow from the fund in the simulation, as the cost of the capital required to meet drawndown ELO commitments
Average tenor of ELO loans drawn down = 4 years	This term of loans is explicitly modeled when considering the inflows and outflows from the fund in the simulation. This assumption may change with further product consultations with potential MFI subscribers
ELO loan write-offs = 1% of loans drawn down	This assumption on non-performing loans is applied when modeling the outflows from the fund in the simulation
Interest on ELO loans drawn down = 6%	The interest on ELO loans is modeled as an inflow to the fund. The 6% is exclusive of non-performing loans, which is considered separately as above. This rate would be agreed upfront as part of the establishment of the contingent credit (ELO) facility for each MFI. The number in the model is subject to change for fund implementation - it will likely vary by institution/country.
Cost of excess of loss layer from GP	The cost of the risk transfer product is modeled based on the total limit required to support the system, and is detailed in the main body of the report. The cost of the product is taken as a multiple of the aggregate modeled expected loss to the risk transfer layer.
Cost of GP data to support ELO products	As the model assumes that access to the ELO facilities from subscribing MFIs depending on a modeled GP view of event severity (parametric trigger), a cost is modeled to account for the use of GP data for contract settlement post-event. This is a number of basis points on the ELO facilities using this data for drawdown.

Model Limitations and Further Work

Models of catastrophe risk provide one of multiple possible valid views of event occurrence. Alternative modeling methodologies will produce different outcomes to those presented herein. The model depends on a number of assumptions listed in the table above. These assumptions have been derived through discussion with VFI and BlueOrchard, or through generic data on the economic/industry environment. They are subject to change for implementation of the proposed FDRM systems, and their alteration will, again, produce significant changes to the model results. Some key limitations of the model, which should be examined and refined for future work, are listed below:

Capturing Correlation of Losses Across the Portfolio

The aggregate index data feeding into the model contains a view of spatial correlation derived from modeled historical event occurrence (1979-2015). Correlation of hazard events between countries is only modeled for the tail of the distribution, where El Nino-type events are considered, causing globally correlated natural disaster conditions. These views of the correlation of hazard occurrence could be further refined.

Limited Stochastic Catalogue

As a result of the structure of the model, a catalogue of 1,000 draws has been chosen as the basis of calculations. A larger number of draws would produce more stability in the results, and should be considered for future iterations of the model.

Preliminary Nature of Cost Assumptions

Once the nature of the DRF entity, (its location and ownership and operating structure), is determined, further refinement of the cost assumptions feeding into the MFI network portfolio model can be made. For example, the source of funds for the starting DRF balance will be determined, and the cost of this capital can be more accurately captured. Similarly, the operating costs for management of the DRF can be further refined. It should be noted as well that the DRF operations will benefit from economies of scale such that the cost of managing the facility will likely shrink as a percent of the total funds as the program grows. This will ultimately reduce the annual access fee that MFIs must pay as a percent of their portfolio.

The Capital Versus Credit Balance

A portfolio-wide assumption has been made for the maximum credit needs for an MFI in the MFI network model (15% of the loan portfolio) and the maximum capital needs (5%). These assumptions are based on experience from a limited number of disasters, and need further refinement. Different assumptions for these numbers will also need to be derived for each MFI, given their operating environments, differing portfolio constituents, and balance sheet starting positions. Changing these assumptions will impact the cost of the system substantially, and the amount of financing required at the global level.

Annex I: Open Access Data

An element of the Rockefeller project involves providing open access to the data that were generated under the grant by Enki Holdings, LLC. Open public access to weather data services has had a long tradition in developed countries and has become more common in developing countries as policy makers begin to observe the benefits of investments in hydrometeorological monitoring for the purposes of risk mitigation and management, both in the private and public spheres. A recent estimate suggests that improved observation and forecasting of hydrometeorological phenomenon could increase global productivity and reduce annual losses by as much as 30 billion and 2 billion USD, respectively (WMO, 2015).

In this spirit of public-goods access and recognition that collaborative efforts in weather monitoring, modeling, forecasting, and financial disaster risk management solutions of all types has the potential to substantively improve and strengthen the livelihoods resilience of the poor, GlobalAgRisk and the Rockefeller Foundation are making publically available the Morrigu™ weather and derived datasets described in section 6. The goal of doing so is two-fold:

- Add value to the efforts of many institutions and individuals for risk assessment and management on behalf of the poor through the provision of this data set that features a consistent and robust methodology and complete record of observations for the provided years.
- Enable researchers to test and challenge the modeled results against alternative numerical simulation methods as a way to raise important questions regarding approaches and methods in order to contribute to the ongoing improvement in hydrometeorological modeling.

The datasets will be distributed via Academic Torrents (http://academictorrents.com), which is a distribution and storage service designed specifically for researchers and academics. The link to the open data can also be found via the GlobalAgRisk website: www.globalagrisk.com

License Agreement and Permitted Use

The dataset will be available for use under a Creative Commons Attribution-NonCommercial-ShareAlike 4.0 International License, commonly denoted as “CC BY-NC-SA 4.0”. Exact legal language for this license can be found here. By downloading the data, the user agrees to the terms and conditions of use. In summary, the license stipulates that the user is free to further share and adapt the data under the following terms:

- The data cannot be used for commercial purposes (Non Commercial);
- GlobalAgRisk must be cited as the source of the data, there must be an indication if the data was changed or transformed in any way, and a link to this license must be provided (Attribution); and
- Any distributed outputs that make use of the data must use this same license (ShareAlike).[1]

A mark similar as given below in Figure 1 will accompany the web-based data access portal to communicate the license agreement.

Figure 1 - Example license mark.

[1] https://creativecommons.org/licenses/by-nc-sa/4.0/