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Final Report for IRI MIEL Planning & Technical Support for HARITA Micro-Insurance Pilot USA 536 /09

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1 Introduction

The Horn of Africa Risk Transfer for Adaptation (HARITA) project is a holistic adaptation risk management project involving three main components: risk reduction, risk transfer, and prudent risk taking. The risk reduction component involves activities such as composting, water harvesting, planting trees, and seed cleaning, and interfaces closely with the Ethiopian Productive Safety Net Program (PSNP), a work for food program through which low income farmers are compensated for their labor in activities such as risk reduction.

Central to the risk transfer component is the development of a next generation index insurance project, that addresses many of the data, scaling, demand, and climate change challenges that have constrained the ability of previous generation index insurance products to meaningfully serve very low income farmers in locations with limited historical rainfall data. This is linked with activities to encourage personal savings, and designed to nurture and compliment other risk management options, including personal savings and risk management oriented community savings pools. Through these risk reduction and risk transfer activities, the project works to encourage the prudent risk taking activities that lead to improved livelihoods, such as the use of improved seeds and agricultural inputs.

Many partners have participated substantially in the effort. Major partners in this project include the Relief Society of Tigray (REST), Dedebit Credit and Savings Institution (DECSI), Nyala Insurance Company, the Ethiopian Productive Safety Net Program (PSNP), the Government of Ethiopian National Meteorological Agency (ENMA), Swiss Re, Mekele University, and Oxfam America. Any successes of the project depend strongly on the outstanding effort, skill, active engagement, and level of insights from the partners. Crop modeling parameters were obtained from LEAP and Mekele University. The project closely interfaces with the PSNP. This project benefits strongly from groundwork and ongoing index insurance pilot projects in Ethiopia and elsewhere by the WFP and World Bank CRMG.

The project is part of the transition into the next generation of approaches necessary to overcome the challenges facing index insurance if it is to help address poverty at large scales. Central to this challenge is to consider index insurance as the last piece of the puzzle. Instead of implementing and scaling index insurance per se, the insurance is designed to help reduce remaining risks after existing development interventions and traditional risk management activities are utilized. The goal is to design and build cost effective, robust, scalable index insurance into a package of development interventions yielding products demanded by low income farmers and workable in data poor contexts.

There have been several index insurance projects around the world, providing a foundation of technology and illustrating its potential[Hellmuth et al., 2009]. At IRI we have contributed to many of these efforts.[1]

[1] At IRI, we have worked to overcome challenges in index insurance in Ethiopia, Ghana, Honduras, Indonesia, Kenya, Malawi, Mali, Nicaragua, Nigeria, Rwanda, Senegal, Tanzania, and Uganda. From these projects, ranging from farmer to macro level, thousands of insurance contracts have been transacted. Partners include

For demonstration of concept, past pilots have focused on the sites that are relatively data-rich, for example, locations for which official government met-stations exist with several decades of historical data. These products have typically been handcrafted by international experts. For products at large scale, the transition must be made to a factory floor, can produce a large number of extremely robust, demanded, and low cost products for which the performance and pitfalls are well known and easily communicated. A key challenge not addressed by these pilots is how to meaningfully offer responsible products for the site for which there is no existing met-station and where there is very little other historical data. However, the goal is not to simply offer insurance at large scales. Instead it is to have insurance be an easily configurable and scalable tool to meaningfully contribute and catalyze holistic risk management, development, and adaptation activities. For local ownership and to address the heterogenous locations, the process must be formally farmer driven, reach very low income clients, rely on the strengths and capacities of local experts and local institutions, and must be integrated with the larger risk management and development activities in each area.

The HARITA project specifically selected sites with very low income farmers and with extremely limited data so that it could provide solutions that might provide meaningful insurance tools for addressing poverty even in challenging locations and difficult to reach clients. The experience so far has been encouraging. As of the date of this report, initial information about the second year of insurance transactions is becoming available. Because the sign up results have not yet been completely tabulated, and the follow up survey has not yet been applied, the official sign up figures will be available in future reports. Although a true assessment of project progress cannot be made until the official sign up information is available and the impact assessment surveys and analyses have been performed, it is worthwhile to note some of the general features of the sign up known at this point.

The project has successfully improved and transferred the model developed in a single site last year to reach the targeted five sites by summer 2010. As with last year, payouts are triggered by satellite estimates of rainfall, with new raingauges put in place for verification. Sign up numbers are still tentative, but early numbers indicate that the number of contracts increased by more than a factor of six. Take up rates appear to be quite high, perhaps exceeding the success of last year. These are for products that are unsubsidized. In addition, due to formal farmer input in the design process, insurance menu options were expanded to include more

the World Bank CRMG, Oxfam America, UNDP, OI, MIA, FIDES, the Millennium Villages Project, Swiss Re, with additional national partners in each location. We have also worked to document the current state of knowledge through the Climate and Society Publication Vol. II (CSP2) process, which is designed to capture the experience, concerns, and innovations of the broader index insurance implementation as it transitions toward large-scale solutions. Partners in the Climate and Society Vol II include Swiss Reinsurance, World Bank, World Food Program, International Fund for Agricultural Development and Oxfam America. The foreword is signed by Kofi Annan. The publication was funded primarily by UNDP and NOAA. Additional partners and funders for Climate and Society II events include MCII, UNU, NSF-DMUU. Institutions from outside of Columbia University that are represented in the writing team include Cornell, Duke, FAO, IIASA, Le Centre Europen de Recherche et dEnseignement des Gosciences de lEnvironnement, NASA, Partner Re, Red Cross, Oxfam, University of Florida, UCSB, University of Reading (UK), Wageningen University (NL), WFP. We have participated in UNFCCC and WCC3 index insurance events.

coverage than last years' products at higher prices. At signup, the overwhelming majority of farmers selected the increased coverage options.

If the experimental insurance contracts from the experimental games are included in the tally, the project has scaled by more than a factor of eight. It is important to note that this experience is for an insurance product that has not been designed solely for the sake of scaling, but designed for the sake of catalyzing the broader risk management activities. Compared to last year, there were several new features intended to improve risk protection, features that might have decreased demand. Educational materials were revised from last year to highlight the weaknesses of the insurance, and encourage farmers to place their resources in other activities. In addition, processes that encourage farmers to select other financial options, such as personal savings or community risk management savings accounts were explored as part of the insurance sign up activities.

The scaling process was driven by farmers, and led by local institutions and local experts. For each new site, a randomly selected focus group session was held, to discuss the risk management issues in the community. A design team was assembled for each site, consisting of community leaders, experts, and farmers specifically elected for the insurance design. Automated weather stations were strategically distributed across the sites. In addition about twenty raingauges were installed across each community to be monitored by local farmers for both educational and index design purposes. A process was followed through which the crops and basic index features were determined by the community design teams through repeated discussions with Ethiopian experts and IRI staff. Prototype indexes were developed using IRI software and analysis tools. Their behavior, strengths and weaknesses were repeatedly discussed with the farmer design committees, insurance and reinsurance companies, and project partners. The goal was to improve the products, to determine which indexes (if any) should be offered in each community, and how they should be packaged to support the broader risk management effort. To provide farmers with the most flexibility in addressing their individual needs, a menu of indexes was offered, ranging in maximum payout and payout frequency.

This process has been complemented by research and development to make progress on the conceptual and technical challenges that must be overcome. We have performed research on the use of satellites to greatly reduce the need for ground measurements of rainfall and flag potential problems at new locations for increased reliability. We have worked on modeling of rainfall processes to build more robust indexes, inform pricing discussions, and provide options for potential future secondary contracts based on ground measurements in case there are concerns about the reliability of satellites for triggering payouts.

Over the past year, the products and approaches have been improved, and the basic scaling processes and tools have been developed so that for the coming year, educational materials can be developed and scaling tools can be configured into an assembly line. In addition, work has been done over the past year, and will need to be continued into the future to increase the technical sophistication of the analysis tools to reduce the labor necessary and increase the reliability and robustness of products to keep pace with the increased challenges of the growing project. We have performed additional analysis of potential climate trends to inform the HARITA project. We have worked on economics research to help inform the project on the key decisions that must be made as we move forward. We have advanced our experimental economic 'games' from last year, making them more realistic to be able to provide research that directly informs issues raised by partners. In these games, we have explored expanded package options such as crops for which the insurance partners wanted more information before implementing commercially, and additional potential savings and risk pool options. For these games, the actual contracts under consideration were utilized, with game payouts determined by the actual satellite rainfall estimates that trigger a commercially implemented product.

HARITA is a project unmatched in the world. The project brings meaningful and scalable products to locations where it was believed that insurance was impossible because incomes were too low and data was too sparse. It is overcoming hurdles in product scaling, affordability, farmer demand, community ownership and design through a vision of insurance as a strategic piece unlocking the potential of a broader climate adaptation and poverty reduction activities. We are a unique partnership, with strong technical and research capacity, years of experience in implementing sustainable community driven development, climate risk, and adaptation projects. We have years of experience in overcoming hurdles for successful index insurance implementations with high demand and dramatic scaling.

This report is the Final Report deliverable for IRI MIEL Planning & Technical Support for HARITA Micro-Insurance Pilot USA 536 /09. The technical annex of this report is the interim Report deliverable for GLO 002/10: General IRI Planning and Technical Support for Harita Micro-Insurance Pilot (IRI Technical Report 10-09, available at http://iri.columbia.edu/publications/id=1004). These works incorporate material from the previous project reports as appropriate. We present the progress made over the past year in arriving at robust and scalable index insurance product designed to compliment, strengthen and catalyze the other components in the HARITA project.

Because this report is being delivered immediately following signup activities and presents analysis done in the past year in support of the design process, it is important to note the tables and figures do not necessarily reflect the final values for parameters that have been updated recently. In addition, because much of the analysis presented in this report has been performed in parallel with, and has led to changes in the indexes, results and comparisons presented at this early stage do not necessarily reflect the final contracts. We intend to update the tables and figures with the finalized values and repeat the relevant analyses for the upcoming October 2010 report, resources permitting.

There are many next steps that must be taken for these efforts to provide evidence of large scale meaningful impacts. The work thus far has focused on forging relationships, processes, technologies, and software that could be marshaled to bring efforts to scale. As a next step it will be important to configure software, develop educational materials and platforms, capacity, and to construct a mass production “assembly line” using the products now available. This will not only be important for scaling, but also to assure that products improve and adapt over time to address changes farmers' situations, the changing climate, and capture knowledge gained over time. In addition, much of the work will need to be automated in order to have it be possible to provide products at scale, with an increasing amount of dependence on local labor and expertise.

It will be critical to have systems in place to flag situations in which the robustness of the product is not satisfactory. It will be valuable to continue the development of solutions that improve performance as well as address problems for a broader range of contexts. It will be important to bring forward the remote sensing, the statistical analysis, and the climate research so that it can systematically improve products, provide probabilities necessary for improved pricing, validate products, and flag potential problems. Economics research, surveys, and experimental games will be important in order to arrive at products that have meaningful roles in farmer's livelihoods. The work to encourage and formally catalyze complimentary risk management strategies, such as agronomic practices and community savings should be extended and deepened. Most importantly, it will be essential to more deeply include partners, local experts, insurers, lenders, and farmers formally into the design, capacity building, implementation and scaling process.

2 Overview of indexes and 2010 process

In 2010, the project was scaled from a Teff in Adi Ha (2009 indexes), to a range of crops over five sites. Figure 1 presents the location of the sites. The Adi Ha contracts were improved and adapted through the HARITA feedback process, leading to insights that impacted the design process in the other villages. For more information on the Adi Ha refinement issues, see section 2.3.

Indexes were designed for farmer-identified crops at each site, including Teff, Sorghum, Maize, and Wheat. As with the 2009 indexes, it was decided that payments would be triggered by satellite estimates of rainfall, with automated met stations installed to evaluate the performance of the satellites, and formal farmer monitoring of rainfall using 20 manual raingauges in each village.

Due to extremely vocal farmer demands, a much more aggressive (and expensive) option was developed for each index as compared with 2009. The two indexes options are listed as "dry" and "very dry" . The "very dry" option, based on the index from 2009, would have had payouts about 1/5th of the time in the past 15 years. This was already a relatively aggressive payout frequency given typical insurance payout rates. Farmers were extremely vocal in wanting a more expensive option that provided payouts at a rate that would have provided payouts approximately 1/3 of the time in the past 15 years. Contracts with this payout frequency do not fit well within traditional insurance experience, so a great deal of effort was required to arrive at a workable model. The indexes were designed to be as robust as possible with the available data quality, with limitations and problems repeatedly

Figure 1: Location of 2010 Sites.

discussed with farmers throughout the design and sign up process.

The indexes were not intended to remove all risks, but simply intended to incrementally reduce risk: providing meaningful payouts in some of the years for which the farmer had problems and reducing the number of droughts that a farmer would have to address through other means. For transparency, and to improve their ability to protect and encourage productive investments, the indexes were designed to yield nontrivial payouts when they were triggered, since extremely small payouts offered for the sake of higher payout frequencies have led to farmer frustration in other projects.

The farmer was presented with a menu of options, with different prices. The farmer could select five different levels of maximum payouts as well as choose between the dry and very dry options. Some farmers paid for the insurance with cash, while others paid using their labor. For some of the new crops, insurance partners wanted more information in order to provide responsible commercial products, particularly given the intended level of scaling of an already experimental product. Therefore, the 2010 commercial transaction involved a subset of the products for which design and pricing was completed. Table 1 presents the details of the commercially offered indexes while table 2 presents the details for the contracts not offered commercially. Note that some of the parameters in these tables are slightly different from the parameters for the indexes utilized in the remote sensing section because the remote sensing analysis was performed prior to the finalization of the indexes (with the intent of improving the indexes).

Each index consisted of one or two "phases," time periods over which the satellite estimates of rainfall are summed. The first phase reflects the onset of the rainy season and the second phase reflects the end of the rainfall season. These are the periods for which the crops are most vulnerable to drought. Because Teff is typically planted in the middle of the rainy season, it is not vulnerable to a weak start of the rainfall season, and therefore its index is a single phase. The farmer design team specified the start and end of each phase through repeated discussions with experts and cross-checking of payout years with historical rainfall data. The rainfall total for each decad, or 10 day period, in a phase is "capped" at the level specified in the table, meaning that any rainfall above that level is not included in contract calculations.

The rainfall total over the phase is calculated and the payout for each phase is calculated using the following formula: Payout = (1-((Rainfall Sum - Exit)/(Trigger - Exit)) * Maximum liability. The phase payouts are summed and capped at the maxiumum liability. The tables present information for each contract, with dates presented in both the Western and Ethiopian calendars. The tables also present the expected payout (the average payout including non payout years). The frequency of maximum payouts and payouts that are smaller than the expected payout are also presented. The tables present what historical payouts would have been over the historical dataset for a maximum liability set to 100, with the years presented in the format of Western calendar year/Ethiopian calendar year.

The 2010 games provided a small scale controlled environment to learn more about an expanded set of the products prior to decisions on commercial implementation and scaling. To improve the experimental games' ability to provide meaningful information beyond that of the 2009 experimental games research, the 2010 games were made as realistic as possible, with farmers working with the actual indexes in question, and the games providing real payouts based on the actual satellite estimates. In order to obtain additional information to aid the insurance companies in their analysis of the indexes not commercially offered, these products were utilized in the 2010 experimental games. The section on the experimental games provides more information, as well as some preliminary results.

2.1 Software for design and capacity building

In the design process, R scripts written by IRI were used for analysis. The Weather Index Insurance Educational Tool, or WIIET, developed under contract with the World Bank ARMT, provides a web-based graphical front end to some of these scripts. Figure 2 is a screenshot from that tool. We intend to rely on this tool heavily in capacity building exercises as the project moves forward.

	Hadush Adi Wheat Dry	Hadush Adi Wheat Very Dry	Adi Ha Teff Dry	Adi Ha Teff Very Dry	Geneti Teff Dry	Geneti Teff Very Dry	Hade Alga Teff Dry	Hade Alga Teff Very Dry
Start 1 (Dek) Start 1 Ethiopian	21-Jun (18) 14-Jun	21-Jun (18) 14-Jun						
End 1 (Dek) End 1 Ethiopian	20-Jul (20) 13-Jul	20-Jul (20) 13-Jul						
Trigger 1 (% ave)	10 (0.34)	5 (0.17)						
Exit 1 (% ave)	0 (0)	4 (0.14)						
Start 2 (Dek) Start 2 Ethiopian	21-Aug (24) 15-Aug	21-Aug (24) 15-Aug	21-Aug (24) 15-Aug	21-Aug (24) 15-Aug	21-Aug (24) 15-Aug	21-Aug (24) 15-Aug	21-Aug (24) 15-Aug	21-Aug (24) 15-Aug
End 2 (Dek) End 2 Ethiopian	30-Sep (27) 20-Sep	30-Sep (27) 20-Sep	30-Sep (27) 20-Sep	30-Sep (27) 20-Sep	30-Sep (27) 20-Sep	30-Sep (27) 20-Sep	30-Sep (27) 20-Sep	30-Sep (27) 20-Sep
Trigger 2 (% ave)	48 (0.94)	25 (0.49)	55 (0.97)	50 (0.88)	48 (0.95)	34 (0.67)	50 (0.95)	37 (0.71)
Exit 2 (% ave)	15 (0.29)	4 (0.08)	40 (0.7)	30 (0.53)	17 (0.34)	17 (0.34)	20 (0.38)	25 (0.48)
Cap	25	25	25	25	25	25	25	25
Expected Payout	20.3	11.2	22.24	14.96	19.71	11.8	17.28	12.08
Payout Frequency	0.33	0.2	0.33	0.2	0.33	0.2	0.33	0.2
Maxpay Freq	0	0.07	0.2	0.07	0.07	0.07	0	0.07
Freq \¡ E Pay	0.2	0	0.2	0	0	0	0.2	0.33
1995/1988	0	0	0	0	42	0	47	10
1996/1989	0	0	0	0	0	0	0	0
1997/1990	98	44	100	100	58	24	41	0
1998/1991	0	0	0	0	0	0	0	0
1999/1992	0	0	0	0	0	0	0	0
2000/1993	0	0	100	54	21	0	2	0
2001/1994	0	0	0	0	0	0	0	0
2002/1995	69	100	0	0	0	0	0	0
2003/1996	0	0	0	0	0	0	0	0
2004/1997	85	24	100	70	100	100	97	100
2005/1998	0	0	0	0	0	0	0	0
2006/1999	43	0	0	0	0	0	0	0
2007/2000	0	0	0	0	0	0	0	0
2008/2001	0	0	2	0	0	0	0	0
2009/2002	10	0	32	0	74	53	72	71

Table 1: CommercialIndexSummary.csv

	Adi Ha Maize Dry	Adi Ha Maize Very Dry	Geneti Sorghum Dry	Geneti Sorghum Very Dry	Hade Alga Sorghum Dry	Hade Alga Sorghum Very Dry
Start 1 (Dek) Start 1 Ethiopian	1-May (13) 23-Apr	1-May (13) 23-Apr	11-Apr (11) 3-Apr	11-Apr (11) 3-Apr	11-Apr (11) 3-Apr	11-Apr (11) 3-Apr
End 1 (Dek) End 1 Ethiopian	30-Jun (18) 23-Jun	30-Jun (18) 23-Jun	31-May (15) 23-May	31-May (15) 23-May	10-Jun (16) 3-Jun	10-Jun (16) 3-Jun
Trigger 1 (% ave)	17 (0.47)	13 (0.36)	17 (0.54)	6 (0.19)	17 (0.43)	15 (0.38)
Exit 1 (% ave)	0 (0)	7 (0.19)	10 (0.32)	0 (0)	10 (0.25)	10 (0.25)
Start 2 (Dek) Start 2 Ethiopian	21-Aug (24) 15-Aug	21-Aug (24) 15-Aug	11-Jul (20) 4-Jul	11-Jul (20) 4-Jul	1-Jul (19) 24-Jun	1-Jul (19) 24-Jun
End 2 (Dek) End 2 Ethiopian	20-Sep (26) 10-Sep	20-Sep (26) 10-Sep	20-Sep (26) 10-Sep	20-Sep (26) 10-Sep	10-Sep (25) 5-Pag	10-Sep (25) 5-Pag
Trigger 2 (% ave)	40 (0.76)	30 (0.57)	115 (0.88)	115 (0.88)	105 (0.79)	95 (0.72)
Exit 2 (% ave)	20 (0.38)	20 (0.38)	70 (0.54)	70 (0.54)	80 (0.6)	88 (0.66)
Cap	25	25	25	25	25	25
Expected Payout	17.8	15.29	18.92	16.41	20.19	11.75
Payout Frequency	0.33	0.27	0.33	0.2	0.33	0.27
Maxpay Freq	0	0	0.13	0.13	0.07	0.07
Freq \¡ E Pay	0.2	0.25	0.2	0	0	0
1995/1988	0	0	0	0	0	0
1996/1989	0	0	0	0	0	0
1997/1990	75	51	0	0	36	0
1998/1991	0	0	6	0	0	0
1999/1992	0	0	100	100	100	100
2000/1993	88	97	0	0	0	0
2001/1994	0	0	0	0	41	17
2002/1995	0	0	32	0	0	0
2003/1996	0	0	0	0	0	0
2004/1997	46	8	46	46	53	46
2005/1998	0	0	0	0	0	0
2006/1999	0	0	0	0	0	0
2007/2000	7	0	0	0	0	0
2008/2001	0	0	0	0	0	0
2009/2002	50	74	100	100	73	13

Table 2: NonCommercialSummary.csv

Figure 2: Screenshot of WIIET software tool

We are also exploring the potential for the use of this tool in the design process. Because internet access is not common in agricultural locations in Africa, we have implemented an experimental stand alone version of the webtool. We have begun developing software to link the database of the stand alone tool with the database of the web version so that design information can be transferred to a central database following site visits. We have used the software for design discussions with experts in Ethiopia and during farmer design team meetings, so that farmer input can be instantly used to update indexes and the farmers can review the results. Figure 3 illustrates use of the tool in a farmer design meeting. We have also begun developing supplementary R code to perform additional analysis and scripting of design processes in communication with the WIIET platform. Throughout this report, many of the figures and tables are the product of this effort. This will be increasingly important with scale up as more people become involved in the design process and a very large number of contracts are developed in parallel that must be packaged for the insurer, reinsurer, and other partners, as well as systematically checked for problems. We intend, resources permitting, to follow up on our initial efforts to arrive at an integrated training/design software package to support scale up.

2.2 HARITA indexes and the interface with savings and traditional community risk management financing

The design process was framed in terms of, how the index might best be strategically designed to enhance other risk transfer, risk reduction, and prudent risk taking activities. Basis risk is a challenge central to index insurance, and in many cases, problematic for other types of insurance. Basis risk is the disconnect between insurance payouts and losses. Insurance of

Figure 3: WIIET software tool use in farmer design meeting

any sort is better suited for larger, less frequent risks. For more frequent risks, savings or informal mechanisms such as borrowing from family can be more cost effective. For index insurance, it is a technical challenge to accurately target smaller risks. In addition, index insurance has basis risk for hazards not indexed and for losses that impact only a few people. Insurance can be an expensive and ineffective option for much of the risk faced. The challenge in the HARITA project is to target the index insurance to the risks it can address effectively and in a way that other potential options cannot. Individual, family, and community savings can play a very complimentary role to insurance. If only a few individuals face loss, it is likely that a community savings account could more effectively provide compensation than a formal index product. However, for large events that hurt the entire community, individual and community resources may be overwhelmed. These are the risks that index insurance is best at targeting. The insurance question is not how much insurance to buy, but how to allocate a farmer's risk management budget across the options available. If the insurance is too expensive, it may be that all of the budget should go towards other mechanisms.

Ethiopia is ideal to build a process in which insurance enhances community risk management because community-based groups, providing insurance-like services and other developmental activities, are already widespread. The most common kinds of such financial risk management services exist in the form of funeral associations, called iddirs. In Ethiopia, funerals involve extensive catering for guests who stay for extended periods of time, resulting in very high expenses. Thus, it is beneficial to belong to an iddir, which ensures a payout for a deceased family member's funeral, in exchange for payments [Dercon et al., 2006]. The average Ethiopian household belongs to approximately 3 iddirs [S. et al., 2008]. The number of iddirs in a village has been found to vary from as many as 80 (i.e. Imbidir, with 350 households) to 5 iddirs in certain villages. There are therefore a large number of iddirs per community, with individuals that are members of several groups.

Iddirs are independent, organized groups and closely resemble formal market institutions in many respects. They have lists of members, written rules and regulations, regular meetings and elected executive committees. In addition, members contribute payments through membership fees, monthly contributions and fines. Payouts occur in cash and in-kind, and can also take the form of labor services. Due to their more formal nature, iddirs are generally inclusive organizations, integrating poorer members and wealthier households [Dercon et al., 2006]. However, iddirs also combine some of the strengths of more informal institutions: well-defined communities and networks make information costs low, and the accepted customary legal system makes it easier to enforce the rules. Iddirs often appear to transcend gender, age, wealth, ethnicity and religion [Bhattamishra and Barrett, 2009]. Finally, iddirs show an ability to evolve and adapt in the context of a changing political environment; they continuously spread and increase in size despite political hostility, and adapt the products they offer [Dercon et al., 2006, Bhattamishra and Barrett, 2009].

Iddirs often hold substantial assets from accumulated contributions, membership fees and fines. Furthermore, this money can be invested into group property in the form of durables. Asset holdings in the full sample of iddirs assessed by [S. et al., 2008] were on average 1,900 birr (USD 190) and peeked at USD 3,000; a considerable sum in a country with a yearly GDP per capita of about USD 100. While funeral risk pooling is the main service offered by iddirs, some alternative products are also being offered by the majority of these groups. These options include short-term loans (governed by strict repayment rules), additional coverage and forms of insurance to cover illness, fire and house destruction. However, probably due to issue of moral hazards, the majority of iddirs in Ethiopia remain focused on funeral compensation [S. et al., 2008]. Overall much risk remains unmanaged, resulting in substantial welfare fluctuations and losses. In addition, due to the relatively small size and localized nature of iddirs, risk pooling is not achieved at a large scale. A major interest of HARITA is to develop processes that compliment and strengthen individual and community savings and risk management.

In discussions about increasing the payout frequency and price of the insurance product, community risk pools such as iddirs arose much in the farmer and expert design team discussions. The 1/3 payout rate farmers preferred was determined in the context of having a complimentary community savings institution that farmers would contribute to in order to address individual risks, more frequent events, and non-drought events. In some of the villages, the community had already established community savings accounts specifically to address drought risk and the discussion turned to how to best implement a formal interface with the insurance to nurture, and benefit from the community risk management.

For the 2010 implementation, these formal interfaces were explored. In the village of Geneti, the insurance purchase included a formal contribution to the existing community savings account. In addition, individual and community savings were part of the experimental games, to help provide quantitative information for index design by observing how farmers balanced their budget between the different savings options and the two insurance products with different payout frequencies.

2.3 Adi Ha feedback and adaptation process

This section outlines the HARITA feedback and adaptation process for the indexes in Adi Ha. Partners reported a 40% loss for teff in 2009, Through discussions with farmers, partners, and experts at Mekele University it appears that 2009 was approximately the 5th worst year in the past 15 for Teff. Preliminary analyzes using remote sensing of greenness presented later in this report are consistent with this estimate, with 2009 being ranked as the 6th worst year out of the past 15 for October vegetative vigor.

The 2009 contract was developed to target the three most severe years out of fifteen, with partners in early 2009 deciding that coverage for more frequent events was not cost effective. In discussions following the 2009 season, farmers and partners argued very strongly that insurance that targets more frequent loss events would be worthwhile, even at a higher price, particularly if the index could be refined to reduce loading and to more effectively target higher frequency events.

The revised 2010 index is based on direction from the Adi Ha farmer design team. There were two types of changes in the index: a reduction in the deductible and improvements in the accuracy of the index (to be able to target the more subtle events associated with lower deductibles).

The deductible of the insurance was reduced by increasing the payout trigger to have larger and more frequent payments. This would extend the coverage to more frequent, lower magnitude events. To achieve this the trigger/exit were adjusted to have an estimated 4-5 payouts in the 15 year rainfall dataset history (33% payout rate).

At this more frequent payout rate, additional refinements in the index were important to reduce the basis risk for lower magnitude, more frequent events. Since the seasonal total for rainfall was less than five mm below average and the rainfall deficits leading to crop loss totaled approximately five mm during the key part of the growing season, detailed discussions with farmers, experts, and stakeholders were required to accurately model the more subtle rainfall deficits of years like 2009. These improvements were to remove 10 days at the beginning and 10 days from the end of the contract period and reduce dekadal cap to 25mm (to place more emphasis on September rainfall).

Because insurance alone does not provide a complete risk management package, it is important for complimentary tools be developed for the future to protect farmers from basis risk as well as risks that fall below the insurance deductible. Potential community saving components of the package could be utilized to provide payouts below the level of the deductible and address basis risk (losses not reflected by rainfall deficit calculations).

In addition, since many crops contribute to livelihoods it would be valuable to offer coverage for crops that were more substantially impacted by lack of rainfall in the 2009 season, particularly in the spring rains. The maize contract was therefore designed for Adi Ha. The contracts for maize would have provided payouts in 2009 due to the weak rains during planting.

3 Experimental Games in Ethiopia

3.1 Introduction

Figure 4: Research Assistant Halefom Gebrekidan explaining about index insurance.

This section provides some preliminary results and details for the experimental games discussed in this report. We have advanced our experimental economic games from last year, making them more realistic, providing research that directly informs issues raised by partners. In these games, we have explored expanded package options, crops for which the insurance partners wanted more information before implementing commercially, and savings and risk pool options. For these games, the actual contracts under consideration were utilized, with game payouts determined by the actual satellite rainfall estimates that would trigger a commercially implemented product. Expanded versions of the actual commercial sign up menu were utilized. Our hope is that farmers are more likely to take the decision making in the games very seriously, since the games themselves provide a small small scale version of the risk protection that would actually be provided by the real index package. If this is the case, the results of the experiment will more accurately reflect what would be expected in commercial implementations. In addition to having research value and being a mechanism that allows farmers to inform product design, the games provide an educational mechanism for farmers to learn about the index insurance packages.

From April 28th to May 3rd 2010, experimental games were conducted in four pilot villages in Tigray, Ethiopia, to try and determine farmers' preferences for managing climate risk. Michael Norton conducted these games for the IRI, in conjunction with REST personnel: Mengesha Gebremichael (facilitator), Samson Abraha (research assistant), Kireab Biraki (research assistant), Halefom Gebrekidan (research assistant) and Dr. Haile Tesfay (data entry and processing manager). For the experimental game proceedings, we selected 100 farmers at random, from each of the four villages, from lists provided by the village. The farmers were selected equally from each of four kushets, in each village, and broken down by gender to ensure proper representation. Due to absences, illnesses, and the inclusion of substitutes, a total of 402 farmers played the games.

These games are imperfect substitutes for actual insurance projects, but offer the project an opportunity to observe behavior in several important ways:

1. The HARITA project is fortunate to be partnered with the Productive Safety Net Program (PSNP), offering farmers who are cash-constrained the option of paying for insurance with labor. The farmers are allowed to work an additional five days in the program to pay for that seasons index insurance, and receive a payout at harvest time if the rainfall is poor. However, the farmers' true motives for participating in this program have not previously been tested. On one hand, they might simply be participating in the program because it offers additional opportunities to earn cash for labor even if that cash is not received every year. On the other hand, they could genuinely see the value in a product like index insurance as a way to manage climate risks, but are simply too poor to participate in index insurance programs otherwise.

2. The experimental games are a tool in figuring out the best way to configure insurance contracts. Pressure from insurance and reinsurance companies accounting for transaction costs desire index insurance payouts to be on the order of every one in five years. However, reports from the field indicate that farmers would prefer that payouts happen more frequently, even if they are smaller.

3. As part of an overall risk management strategy, through these games, the participants were discussed the concept of a community risk pool and offered an opportunity to invest in it as part of the game. This somewhat complex concept usually requires the initiative of the village in order to be properly organized and managed. Using the games, the project was able to explore this risk management strategy and observe how participants responded to learn about their feasibility in sites without community drought savings as well as their relationship to insurance in sites with established drought savings pools.

3.2 The Game: How to Play

The exercise was to observe farmers' choices as they were given 70 birr (5 USD) and ask to divide the money as they chose among five options for managing risk. The research team had to carefully explain each option to the farmers in order to make sure that they understood all five very clearly. In each village a training exercise was given in which the difference between several different types of risk-hedging instruments were shown. As part of this exercise, the farmers were first taught about the difference between savings and insurance

Figure 5: Drawing a red ball during an experimental games session.

through simulations (no money was transacted), as they were asked to place "money" into either a savings account or an index insurance contract. To simulate the results of the season, 15 colored balls were placed in a box with historical probabilities corresponding to the precipitation patterns in previous seasons. If a red ball was chosen (3/15), it was considered a very dry year, a yellow ball (2/15) was a slight dry year, and green (10/15) corresponded to a good year. Based on the ball chosen, the results of the differences between savings and insurance were calculated and communicated to the farmers.

All money placed into savings will always be returned with a 10% bonus , but the money placed in the index insurance depended on the ball chosen. If a yellow or red ball was chosen at random, the farmers received twice the amount that they placed into index insurance, mirroring the payout and frequency of the slight dry insurance. If a green ball was selected than the farmer received no payout and the money invested in the insurance was not returned.

Once this exercise was completed and repeated two to three times, to highlight the different outcomes possible for years with good and bad rainfall, the game became more complicated. The farmers were told that there were in fact two types of savings (personal and community-based), as well as two options for index insurance, which had identical expectations of total payment, but paid out in a different number of years.

After the training period was complete, the farmers were each given the 70 birr to transact with and chose amongst the five options for managing risk outlined below. The estimated returns on the invested money remained a simplification of real-world rates. For example, the savings account could be expected to have a high rate of return, but perhaps not exactly 10%. The index insurance would pay out on a schedule based on the total rainfall for the year, and would only pay out at the maximum in a very bad year. The frequencies and payout rates

	Slight Dry	Very Dry
Start 1	1-May	1-May
End 1	30-Jun	30-Jun
Trigger 1	17	13
Trigger 2	0	7
Start 2	21-Aug	21-Aug
End 2	20-Sep	20-Sep
Trigger 2	40	30
Exit 2	20	20
Dekadal Cap	25	25

Table 3: Adi Ha and Awet Bikalsi Maize Game Contract.csv

	Slight Dry	Very Dry
Start	11-Jul	11-Jul
End	20-Sep	20-Sep
Trigger (capped mm)	125	115
Exit (capped mm)	70	70
Dekadal Cap	25	25

Table 4: Geneti Sorghum Game Contract.csv

as presented were intended for educational goals only, but illustrate the differences between the two types of contracts.In summary, the five risk management options were:

1. Keep the money. The farmers could keep any portion of the 70 birr that they desired.

2. Invest in a savings account. Any money put into this option would be paid out in October with a 10% bonus.

3. Community Savings Fund. Any money put into this option would be put into a fund that is controlled by the community and will go to those people that the community thinks should get it in October.

4. Slight Dry Insurance. The farmers were also given the option of paying for some insurance for their crop, which is based on the rainfall.

5. Very Dry Insurance. This is the second option for index insurance, and covers years, which have more severe droughts.

Tables 3, 4, 5, 6, 7, and 8 present the details of the indexes used in the game.

Year	Year (Ethiopian Calendar)	No Payment	Slight Dry	Very Dry
1995	1988	0		
1996	1989	0		
1997	1990	0		
1998	1991		XX	
1999	1992		XX	XXXX
2000	1993	0		
2001	1994	0		
2002	1995		XX	
2003	1996	0		
2004	1997		XX	XX
2005	1998	0		
2006	1999	0		
2007	2000	0		
2008	2001	0		
2009	2002		XX	XXXX
Total			10	10

Table 5: Geneti Sorghum Hist Freq Payouts.csv

	Slight Dry	Very Dry
Start	1-Jul	1-Jul
End	10-Sep	10-Sep
Trigger (capped mm)	130	105
Exit (capped mm)	80	80
Dekadal Cap	25	25

Table 6: Hade Alga Sorghum Game Contract.csv

Year	Year (Ethiopian Calendar)	No Payment	Slight Dry	Very Dry
1995	1988	0		
1996	1989	0		
1997	1990	0	XX	XXX
1998	1991			
1999	1992			
2000	1993	0	XX	
2001	1994	0		
2002	1995			
2003	1996	0		
2004	1997		XX	XXXX
2005	1998	0	XX	
2006	1999	0		
2007	2000	0		
2008	2001	0		
2009	2002		XX	XXX
Total			10	10

Table 7: Hade Alga Sorghum Hist Freq Payout.csv

Adi Ha and	Awet Bikalsi	Maize		
Year	Year (Ethiopian Calendar)	No Payment	Slight Dry	Very Dry
1995	1988	0		
1996	1989	0		
1997	1990		XX	XXX
1998	1991	0		
1999	1992	0		
2000	1993		XX	XXXX
2001	1994	0		
2002	1995	0		
2003	1996	0		
2004	1997		XX	
2005	1998	0		
2006	1999	0		
2007	2000		XX	
2008	2001	0		
2009	2002		XX	XXX
Total			10	10

Table 8: Historical Freq of Payouts.csv

Location	Percent Buying Insurance	
Adi Ha	95.92%	
Awet Bikalsi	100.00%	
Geneti	100.00%	
Hade Alga	100.00%	

Table 9: Percent Ppl Buying Index Insurance.csv

	Keep	Savings	Comm	Dry	Very Dry
Adi Ha	100.00%	77.55%	34.69%	91.84%	4.08%
Awet Bikalsi	100.00%	99.07%	56.07%	97.20%	2.80%
Geneti	95.92%	97.96%	88.78%	78.57%	21.43%
Hade Alga	100.00%	97.98%	89.90%	75.76%	24.24%

Table 10: Percent Putting Some Money Into Option.csv

	Keep	Savings	Comm	Dry	Very Dry
Adi Ha	61.24%	12.85%	4.09%	20.51%	1.31%
Awet Bikalsi	43.90%	20.08%	6.07%	29.29%	0.67%
Geneti	26.20%	18.05%	10.92%	36.32%	8.52%
Hade Alga	27.54%	18.89%	11.90%	30.93%	10.74%

Table 11: Percent of Total Spent.csv

Village	Keep	Savings	Comm	Dry	Very Dry
Adi Ha	4195	880	280	1405	90
Awet Bikalsi	3290	1505	455	2195	50
Geneti	1800	1240	750	2495	585
Hade Alga	1910	1310	825	2145	745

Table 12: Totals in Birr.csv

3.3 Preliminary Results

Tables 9, 10, 11, and 12 provide some initial summaries of the game outcomes. Note that since the rainfall season is not yet complete, the final payments have not yet been made and the follow up game activities have not been performed.

The preliminary results contain several important pieces of information. First, it is important to note that the overwhelming majority of participants bought at least some type of index insurance. The 4% who did not buy index insurance were in only one village (Adi Ha). Second, the slight dry insurance was strongly preferred to the very dry option. Most farmers indicated that they preferred to have more frequent payouts, even if those contracts were more expensive (relative to payout size). One farmer also indicated that he had no trouble meeting his obligations in a slight dry year but needed help in the very dry years. Third, the percentage of people contributing to the Community Risk Pool is noticeably higher in the sorghum areas of Geneti and Hade Alga. This was attributed to several factors, the most important of which might be that there are already community organizations active there that are providing many of these similar functions; thus the participants are very comfortable with the management of these groups and understand their value in providing protection against idiosyncratic risks. These community groups are not well established in the maize areas of Adi Ha and Awet Bikalsi. Part of this reason can be attributed to the religious beliefs of the farmers in that area. In Geneti and Hade Alga, more farmers are Muslim, and therefore will not engage in transactions that include interest. As a result, the community organizations in this area provide a mechanism to lend and save money.

It also should be noted that the difference in money kept between the two areas (sorghum verse maize) is quite distinct. Some possible reasons for this include:

- At the time of the games, farmers in the maize-growing areas had not yet planted their crops. Thus having money was extremely important to them, so that they could invest in inputs.
- Index insurance contracts and index insurance games had already been performed in Adi Ha, which may have impacted their decisionmaking.
- Farmers in Adi Ha are accustomed to receiving a per diem for participating in focus groups and may have been expecting a payment ahead of time.
- Farmers in the maize-growing area were more confident that this season (2010) would be a good season for maize, while the farmers in the sorghum-growing areas were not very confident. (There were distant rain showers visible from both areas during the game activities.)
- The farmers and extension experts in Geneti and Hade Alga indicated that the last three years had been sub-par for rainfall. This manifested itself in decreased numbers of livestock, who were now being fed with cacti harvested from local mountainsides.

- The training crew had increasing effectiveness as the games progressed and they gained experience. The first session in Adi Ha, in particular, had less research assistants than at any other time and the participants may have been unclear as to the exact options that were available.

These are merely observations, as the results are only preliminary, and because the rainfall season is not yet over, the game itself is not complete. We are in the process of analyzing the game selections, as well as the game participant survey data. Processing of the results of the game is ongoing and there are some larger questions that will require more extensive analysis, such as the effects of PSNP participation on willingness to buy insurance.

3.4 Diagnostic Analysis of Potential Trends

In [Dinku et al., 2009], we presented analysis of regional rainfall data across Ethiopia to look for evidence of trends in the early Spring and late fall. These analyses suggest that there may be evidence for a drying trend in the early spring but that there was little evidence of a drying trend in the fall. Because the additional contracts for 2010 include payouts for the late spring/early summer (April-May-June), we have performed additional to include this period. Figure 6 shows the historical rainfall data from several sources averaged over much of the Horn of Africa (see the 2009 report to Oxfam for the exact region), and figure 3.4 performs the same calculation for a box covering most of Ethiopia. Figures 8 and 8 repeat the analysis for the late summer/fall (August-September-October). More statistical analysis is necessary for concrete assessments, but by visual inspection, it is difficult to identify a drying trend over the past five to ten years in any of the data sets, although there may have been a movement towards less precipitation a little over ten years ago for the April May June season. Again, more analysis is necessary to be able to make factual assessments.

We have performed initial investigations in trends in drying during filtered contract windows or for increased payouts for the 2010 contracts, including the redesigned Adi Ha Teff contract. This analysis is only in its early stages, but drying trends or trends in increasing payments do not seem to be evident in the 2010 contracts at this stage of the design.

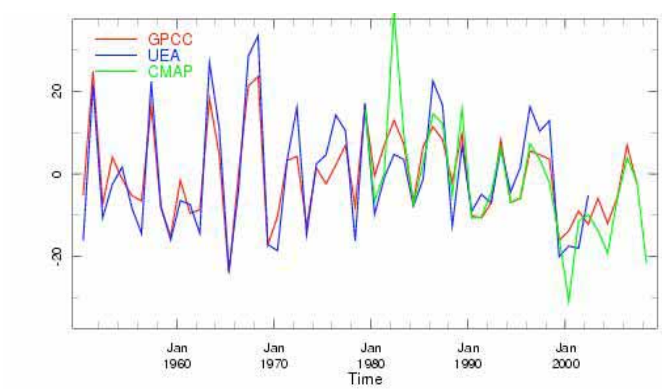

Figure 6: April-May-June Full Domain Rainfall departure from common 1979-2002 base period average

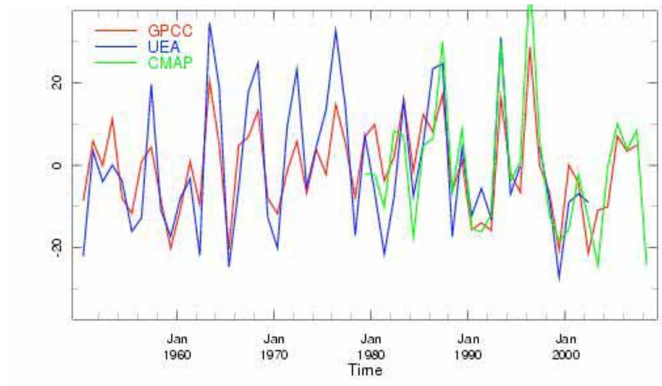

Figure 7: April-May-June Ethiopia Rainfall departure from common 1979-2002 base period average

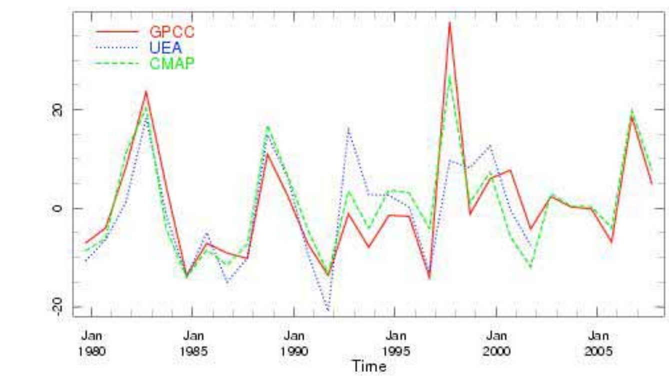

Figure 8: August-September-October Full Domain Rainfall departure from common 1979-2002 base period average

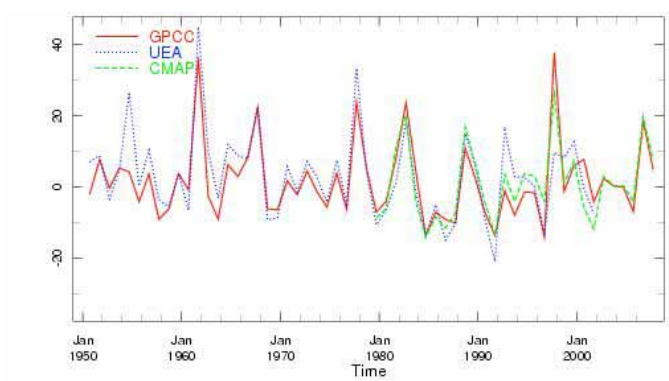

Figure 9: August-September-October Ethiopia Rainfall departure from common 1979-2002 base period average

4 Remote Sensing

4.1 Introduction

In creating robust and accurate index insurance contracts for the HARITA project, it is critical to have a reliable way to estimate crop growth/loss, in order to design contracts and identify triggers. While farmer feedback is important in determining poor growing years, it also remains crucial to build a system that relies on verifiable data. On-the-ground sensing instruments, such as rain gauges, are valuable scientific tools, however these too present some complications. These technologies can be expensive to implement and limited geographic spacing can create difficulties in contract design. The use of remote sensing (satellite) technologies to leverage the limited amount of ground-based information may make the up-scaling of weather index insurance feasible, as long as robust, responsible, and cost effective techniques can be employed for calibration and validation.

Currently, the HARITA project utilizes ARC satellite rainfall estimates to trigger payouts. It is important to identify the areas where remote sensing of rainfall is not an accurate mechanism to build contracts. Sometimes ARC data has difficulty reflecting actual rainfall and/or crop loss. For example, geographic boundaries, such as mountains, where rainfall measurements vary greatly due to localized weather patterns, can limit reliability. It is essential to identify locations where these problems may occur. To address this problem we are investigating various other remote sensing tools that estimate greenness, the vegetative vigor of plants. These are often referred to as vegetative indices, and are described further below. Our eventual goal is to develop processes through which remote sensing of vegetation can leverage the minimal ground level information available to accurately perform this role, and perhaps to be utilized as part of the index product.

The remote sensing activities in this report can be organized into three categories

1. Satellite estimates of rainfall for index calculations.
2. Exploratory validation of satellite rainfall estimates using off the shelf satellite vegetation sensing products.
   (a) Sites: Hade Halga, Geneti, Awat Bikalsi, Adi Ha, and Hadush Adi
   (b) Years: 2000-2009
   (c) Season: Late summer (phase 2 of contracts, flowering and filling phases for crops)
3. Determination of what the vegetative satellite imagery actually represents so that it can be appropriately utilized and improved for validating and mapping problem areas in satellite estimates of rainfall. This activity includes:
   (a) Ground verification activities comparing the dry and wet seasons in Adi Ha

(b) Exploratory use of rare but high resolution satellite images to determine if they can be used to reduce the amount of necessary ground verification information

4.2 Remote sensing of rainfall

The 2009 contract used remotely sensed estimates of rainfall to determine payouts, and we have been using the same products to develop all of the indexes for 2010. The product used is NOAA CPC ARC, available directly from NOAA as well as through the IRI data library. The draft indexes presented in the 2010 contracts are all based on remote sensing of rainfall. In addition, IRI has been working with the Ethiopian Met service and other partners to develop more accurate remotely sensed estimates of rainfall, and to expand the length of the of the data historical series from 15 years to 30 years. In this activity, the Ethiopian Met service will utilize their archive of historical data to develop improved and extended satellite rainfall estimates.

Much of the analysis for remote sensing of rainfall is the development of systematic statistical methods to combine and compare and validate the rainfall data against vegetative sensing, ground measurements of rainfall, and other data sources. See the section on statistical methods for more description of these activities.

Ground measured rainfall is the most critical measure to compare satellite rainfall estimates. Figure 10 shows the location of available ground based met stations in relation to the sites for 2010. Many differences between the dataset are not problematic for index insurance so long as the index can be strategically designed to avoid having these differences lead to missing or inappropriate payouts. For example, differences in exact daily rainfall levels are not critical if the total over the contract window reflects droughts. In addition, if the rainfall estimates are systematically higher or lower than ground observations, that is not a problem if the years with low precipitation estimates in the satellite data sets are the same as those in the ground measurements. The figure includes the three new automated met stations installed as part of the HARITA project.

4.3 Off the shelf vegetative sensing satellite products

One emerging methodology for overcoming sparse field data is to measure levels of precipitation and/or vegetation from a remote sensing platform. Currently, the HARITA utilizes ARC data for index payouts, a remote-sensing product used to estimate rainfall amounts. In previous years, these values have been compared to station gauge data at Maychew, Adishewshu and Alamata to test for accuracy. However, remote sensing tools that measure levels of plant growth, or vegetation, may also represent what is happening on the ground and may provide another means of verification, as well as a possible future source for deriving contracts. In order to test this idea, we compared five different off the shelf satellite-based

Figure 10: Geographic placement of new villages and existing rain gauges.

indices, of which four are derived from the presence of chlorophyll (or the greenness in vegetation) and one from the presence of water in the vegetation; each of these products varies spatially and temporally in resolution.

NDVI is the most widely used satellite vegetative index. It is available from the early 1980s to the present for most of the world, with several images per month. NDVI stands for Normalized Difference Vegetation Index and senses the greenness in a given area by measuring the wavelengths of light that are reflected off the surface. Plants have evolved to absorb some wavelengths of light for photosynthesis as well as reflect those wavelengths of light which are harmful to them. By measuring the relative ratio of the two wavelengths, we can passively monitor vegetation on the earth's surface from a satellite at various points in time.

There have been some index insurance projects that use indexes like NDVI for the basis of their contracts, such as the project by Chris Barrett of Cornell in the rangelands of Kenya. At IRI we have designed NDVI triggered contracts for village level index insurance contracts for nearly a dozen countries in Africa for the MVP project. These contracts have been transacted in Kenya and Ethiopia. NDVI is very different from rainfall indexes, especially in a place like Ethiopia which has much mixed vegetation such as bushes and trees which could confuse the measurement. Also, factors such as soil reflectance, solar angle, cloud cover, satellite angle, and differences between satellites must also be taken into account.

We are conducting these investigations not only to gain more insight of conditions on the ground, but also with an eye to potential enhancements in the contract. Depending on the results of the research, it might be advantageous to include NDVI data in our contracts so the the final product is a mixture of rainfall and NDVI data. Currently, we are utilizing NDVI as an independent source of information to validate the performance of rainfall based indexes, including those based on remotely sensed rainfall estimates. We are also very interested in using vegetative sensing to map the area for which a given rainfall based index can accurately protect. NDVI data is easily accessed through the IRI's data library most of the globe, which allows us to study the data for our various sites in Ethiopia, and provides data delivery avenues convenient for going to scale.

These indices include:

1. Normalized Difference Vegetation Index (NDVI-AVHRR) from the National Oceanic and Atmospheric Administration (NOAA), which is measured every ten days at an 8km spatial resolution.
2. NDVI-Spot Vegetation Index from the Centre Nationale d'Etudes Spatiales (CNES), which is measured every ten days at an 1km spatial resolution.
3. NDVI/MODIS Vegetation Index from National Aeronautical and Space Administrations (NASA), which is a 16-day composite index measured at a 250m spatial resolution.
4. Enhanced Vegetation Index (EVI) derived from the same sources as NDVI/MODIS, but has a different quantitative relationship that is more sensitive to canopy structure and type.
5. Normalized Difference Wetness Index (NDWI) also derived from the same sources as NDVI/MODIS, but reflects changes in the vegetations water content.The MODIS-derived indices (number 3-5) are only available starting from the year 2000, while the NDVI-Spot vegetation index is available from 1998; NDVI-AVHRR is used starting from 1995. Thus, when comparing these sources of information we start with the year 2000. It is very important to have a long enough time series in order to capture the frequency of drought. Unfortunately, the highest quality products are new and data collection has not occurred for as long as desired. Therefore, it is important to try to figure out the reliability of older products and a robust combination of both tools.The comparison of these different vegetation indices against the rainfall gauges and the ARC satellite-derived rainfall estimates can help understand the applicability of vegetative remote sensing tools to incorporate into the design of index insurance products.

These vegetative index satellite products have substantial limitations for their use. Many products are distorted by satellite view angle, solar illumination angle, atmospheric dust and humidity, bare earth, clouds, changes in satellite sensors, compositionally mixed pixels and other factors. Since these products measure the vegetative vigor (or for some products, the soil moisture) over a particular region, in order to understand what they are indicating, it is important to understand the land cover in the region. Typically, the agricultural crop being insured is not the majority of the vegetation. Instead, the products see mostly grasslands, trees, or bare earth. Understanding what is being observed is necessary to use the products. In addition, many crops (such as maize) can have vigorous, green foliage without producing much grain. The satellite vegetation indices are therefore not used as direct measurements of the health of the crop. Instead they are used strategically to proxy the response of the landscape to rainfall. For example, the index may be used to determine if catastrophically low levels of rainfall occurred during a key month for the crops being insured, by observing if the surrounding grasslands lost their vegetative vigor in the month following key rainfall.

For the initial diagnostic of these products, we focus on the second phase of the indexes, and the vegetative sensing in the month following the rainfall. Typically, the vegetative response to rainfall lags the actual rainfall by about a month. We compare

- Capped satellite estimated rainfall for the second phase of the contract. (ARC)
- Capped rainfall from nearby raingauges. Note that these raingauges are expected to experience different rainfall patterns from the index site, either due to distance or features such as mountains. The raingauges were not considered sufficiently related to the index site to be workable as triggers for payments.
- Initial farmer design team reporting of "bad" years. Note that these years include problems related to sowing, and in some cases are not specific to the crop being presented. In follow up design meetings "bad" years were identified by the farmers in much more precise terms. We hope to repeat the presentation utilizing the updated information.
- WRSI, a useful, but limited agronomic water stress calculation used in the design software, based on the ARC rainfall estimates.
- The remote sensing indices listed above for one month after the rainfall window.

It is important to note that this exercise was performed in parallel with the index design and used in discussions to improve the indexes. Therefore the index windows used for rainfall ranking in this analysis are not necessarily the finalized contracts. Resources permitting, we intend to repeat the analysis with the finalized information.

As would be expected, results from using the off the shelf vegetative sensing products and nearby raingauges are mixed. The datasets reflect many of the major events as bad years. However, many major events are not reflected in the indexes and the indexes have a substantial amount of disagreement between them. Table 13 is an example of one of these comparisons, presenting the information for Teff in Hade Alga (the technical annex presents these comparison tables for more indexes and sites). We compare the rankings to see if the worst years are reflected in the other datasets. This past year was the worst or second worst year across all of the available datasets, and was noted as "bad" by the farmers. Widely recognized as being a drought year, 2004 is the worst in the ARC dataset, the eighth worst year in two of the raingauge datasets, the fourth worst year for the NDVIg-rg (the vegetative

Yr	ARC	Maychew	Adisheshu	Alamata	Farmer	WRSI	NDVIg-rg	SPOT-Veg	MODIS	NDWI	EVI
2000	8	1	6	1	-	6	1	1	1	1	1
2001	3	3	1	8	-	7	2	1	4	7	3
2002	6	2	9	3	-	5	4	3	2	2	2
2003	1	6	7	9	-	2	5	4	3	8	4
2004	10	8	8	5	Bad	9	7	6	5	9	6
2005	5	9	4	6	-	4	6	8	8	6	8
2006	7	5	3	4	Bad	8	3	7	6	5	7
2007	4	7	2	7	Bad	3	8	5	7	3	5
2008	2	4	5	2	Bad	1	9	9	10	4	10
2009	9	#N/A	#N/A	#N/A	Bad	10	10	10	9	10	9

Table 13: Hade Alga Teff Ranking.csv

	Adi Ha Maize	AdiHa Teff	Hade Alga Teff	Geneti Teff	Hadush Adi Wheat
NDVI	2	2	2	1	1
SPOT Veg	3	2	2	2	1
MODIS	1	0	1	1	2
NDWI	2	2	2	1	1
EVI	2	1	2	2	2

Table 14: 3 in 5 Worst Years.csv

index with the longest history but the least advanced), and the second worst year for the NDWI, a wetness index. It is important to note that 2004 is in the worst half of the other indices, but is not indicated as a particularly bad year.

Interestingly, 2008, is an extremely bad year for all of the vegetative indices (except for the wetness index) while all of the rainfall measures indicate either average or very high levels of rainfall. Since the farmers reported 2008 as a bad year, it may be that the vegetative indices are picking up a meaningful signal that is for reasons somewhat different than simple measures of rainfall. It may be, that with more research, vegetative indexes may play a valuable complimentary role to water measurements in creating a more effective index in the future. In the Millennium Villages Project, for a site with much more data for design than is available in the HARITA project, we developed an index that was a blend of remote sensing of vegetation and ground based rainfall measurements. This index outperformed both of the component indexes.

Table 14 presents a summary of the vegetative indices across the sites. It presents a sum of how many of the three worst ARC years are represented in the worst half of the different indices. One can observe that in most cases about two of the worst ARC years fall in the worst half of the years of any vegetative index, although there are many cases for which there are fewer years. It is not clear that any particular vegetative index greatly out performs another, although SPOT Veg and EVI tend to have the highest level of agreement with the ARC rankings.

This initial analysis of off the shelf vegetative products serves to motivate our research into the improvement of vegetative sensing. It suggests that in spite of their known limitations there may be real promise in the use of vegetative sensing to validate satellite rainfall indexes if their behavior can be better understood. The vegetative indices may also at some point be valuable in improving a precipitation based index. However, at this point it is difficult to get robust or consistent performance from any of the off the shelf products. this work also shows that it will be critical to continue this work to improve upon and better understand the performance of existing products in order to provide robust, responsible, and reliable metrics.

4.4 Project research activities on remote sensing of vegetation

While simple vegetation indices can indicate the presence, absence and in some cases change in vegetation cover, these indices are vulnerable to bias from exposed soil and cannot generally distinguish between indigenous vegetation and agriculture. The difference is important because agriculture and indigenous vegetation generally have different phonology (green-up and senescence periods) and response to rainfall. The wide field sensors used to monitor temporal changes in vegetation indices are also limited in their spatial resolution to pixel dimensions of 250 x 250 meters or more typically 1000 x 1000 meters. Hence, the vegetation imaged in most pixels will be some unknown spatial mixture of agriculture and indigenous vegetation. However, both the spatial heterogeneity of mixed pixels and the distinction between agriculture and indigenous vegetation can be addressed with the use of additional imagery with higher spatial resolution and more sophisticated methods for estimation of vegetation type and abundance.

We are developing a strategy of multi-resolution spatial-temporal analysis with telescoping validation. This approach addresses the issues described above by using a combination of high temporal resolution (daily to 8 day composite), low spatial resolution (250-1000 m) MODIS imagery with moderate spatial resolution (30 m) , low temporal resolution (16 day) Landsat imagery and high spatial resolution (2.4 m) Quickbird imagery collected on specific dates. The MODIS imagery resolves spatial variations in the temporal phenology but cannot distinguish the relative abundance of agriculture and indigenous vegetation. The Landsat imagery can distinguish different types and abundances of vegetation at plot scales but only as snapshots on specific dates. The Quickbird imagery can resolve individual trees, bushes, herbaceous understory and agriculture but only on the date the image is acquired. We are able to combine the information provided by each sensor into a single spatial-temporal map of vegetation type, abundance and phenology through the use of spectral mixture analysis (SMA).

SMA provides a robust, scaleable, and verifiable method to identify spectrally pure endmembers (e.g. illuminated foliage, soil, water, rock, shadow) and estimate the spatial abundance of each within spectrally mixed pixels (Adams et al, 1986; Smith et al, 1990). SMA can be applied to both Landsat and Quickbird imagery allowing the field-verifiable estimates from the Quickbird imagery to be used for quantitative validation of the Landsat-derived estimates of the same endmember abundances at 30 m resolution. Accuracy of vegetation abundance estimates from Landsat have been quantified at 94% in previous studies (Small and Lu, 2006). The telescoping validation approach uses field observations to verify vegetation type in Quickbird imagery then uses Quickbird-derived mixture fractions to validate Landsat-derived mixture fractions to distinguish different vegetation types and abundances at regional scales.

We expect that validation of Landsat fraction estimates in both wet and dry seasons should allow for distinction of indigenous vegetation and agriculture at plot scales. This will allow us to combine seasonal maps of vegetation type and abundance from Landsat with spatial phenology maps derived from MODIS to distinguish the aggregate phenology of different mixtures of agriculture and indigenous vegetation at scales of 250-1000 meters. By comparing the phenology of a given year with the phenology from previous years, it should be possible to quantify anomalous rates of green up and senescence in different areas and to identify the relative abundance of agriculture and indigenous vegetation contributing to the aggregate phenology observed by MODIS.

We conducted two visits to Tigray in 2009 to better inform satellite vegetation measurements by providing contrast between dry season vegetation (in March), such as bushes, trees and crops, and that just before harvest (in October), in the period of their greatest extent. These visits provide the ability to analyze the appropriateness of utilizing remote sensing data and how accurately remote sensing techniques reflects on-the-ground observations. The May visit was conducted by Dr. Christopher Small and the November visit was by Michael Norton. The field validation in March was conducted using a January 2006 Quickbird image for comparison.

Because the presence of indigenous vegetation in non-agricultural areas does not generally change from year to year the primary differences are expected to be related to interannual variability of precipitation (for drought sensitive herbaceous vegetation) and grazing by goats (for smaller shrubs and herbaceous vegetation). In the course of this investigation, approximately 20 landscape panoramas and 50 GPS waypoints were recorded during each visit. To see the difference between the non-agricultural season and when the crops are being grown, see Figures 12 and13 which are the same subsection of one of the landscape panoramas (figure 14). Figure 12 was taken in the March groundtruthing trip and clearly illustrates the lack of greenness before the cropping season has begun. Figure 13 illustrates the same view in October, and is much greener. By comparing the two time periods, we can better understand how well remote sensing may be able to proxy crop vigor.

In spite of potential differences, a very strong correspondence was found between the 2006 Quickbird image and the 2009 vegetation cover. Using the GPS geotagged field photos in conjunction with the Quickbird imagery we were able to associate different dry season vegetation fraction abundances with different amounts and types of herbaceous cover identified in the field.

We are currently developing spectral mixture models for both the Landsat and Quickbird imagery to conduct vicarious validation of the Landsat-derived vegetation fraction estimates at 30 m pixel scale. We are comparing the Jan. 14, 2006 Quickbird image with the two closest Landsat acquisitions from Dec. 2006 (julian day 344) and February 2009 (j.d. 43) to quantify both the temporal change and agreement with the higher resolution validation data. These vegetation maps will then be compared with that derived from the Landsat image acquired Feb. 2009 (j.d. 51) to further quantify the multi-temporal uncertainty in the dry season estimates. The dry and wet season vegetation differences will be mapped using Landsat fractions from Feb. 2009 and Oct. 2009 (j.d. 309). These fraction estimates will be used to calibrate the 2000-2010 MODIS EVI. By using high resolution imagery to understand what off the shelf products are representing, our hope is that the off the shelf products can be corrected in order to perform well in validating the performance of rainfall estimates. If the performance of the off the shelf products can be sufficiently improved, they may also play a role in the future as part of the index itself.

Figure 11: Teff crop in Adi Ha, October 2009.

Figure 12: Adi Ha Landscape photograph from groundtruthing exercise– May.

Figure 13: Adi Ha Landscape photograph from groundtruthing exercise–October

Figure 14: Panorama containing view in previous two figures.

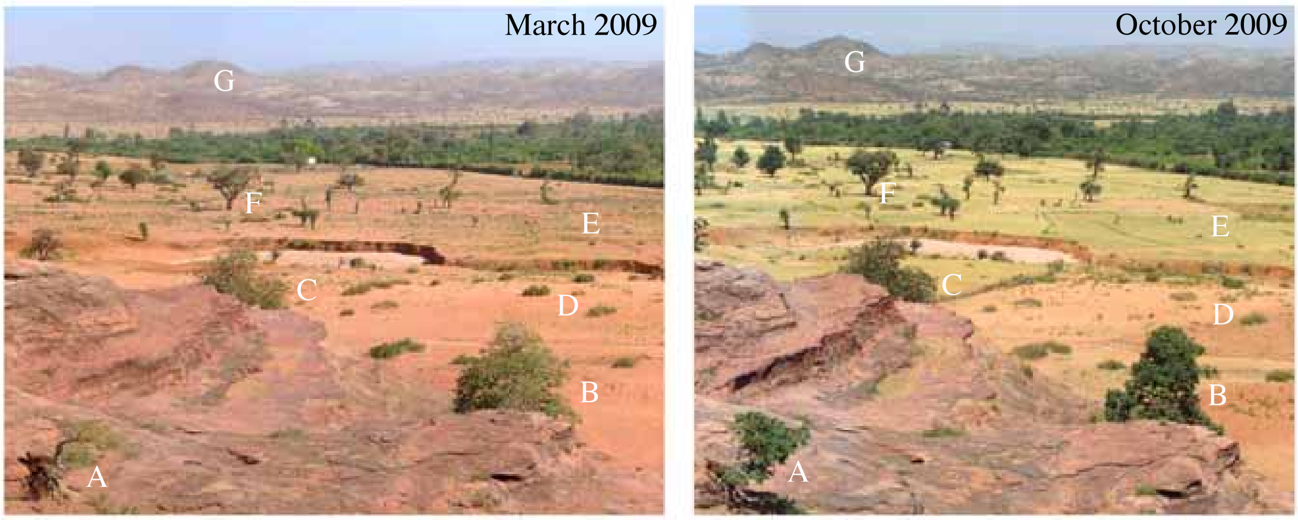

Figure X Wet and dry season comparison of orchard and fields west of Adi Ha village. Some slight differences in vegetation phenology are apparent for shrubs (A), and trees (B, C, F). More pronounced differences are seen in agricultural fields - particularly at boundaries (D, E). The far hill slopes (G) are darker because of both tree foliage and resulting shadow.

Figure 15: Wet and dry season comparison west of Adi Ha

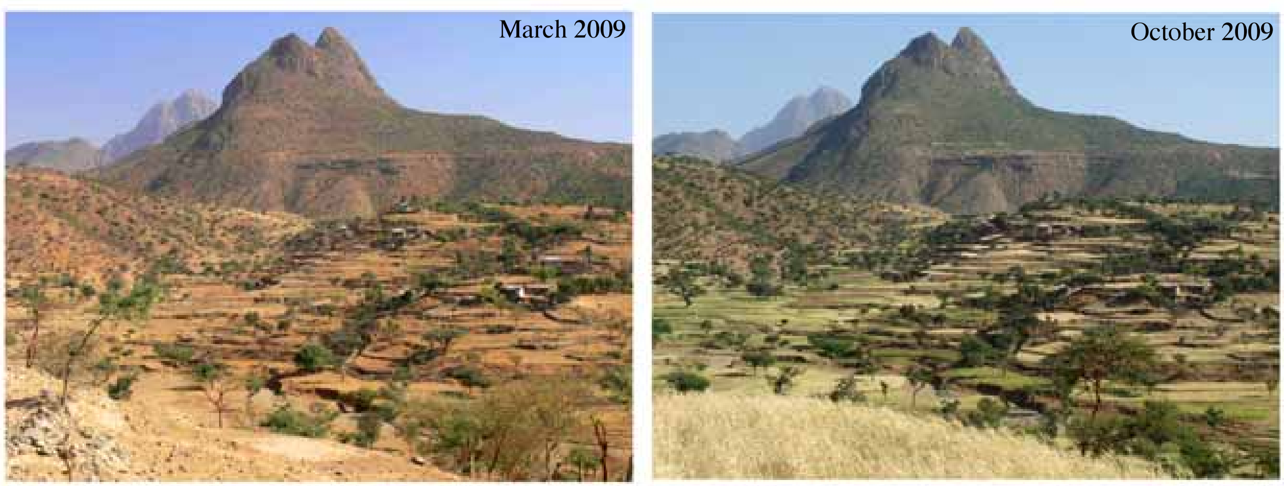

Figure Y Wet and dry season comparison of agriculture and indigenous vegetation north of Adi Ha. As in previous example, the indigenous trees are a bit more leafed out and casting deeper shadow in October. The most pronounced difference is in the increased greenness of the agriculture. Note extensive intermingling of trees and agriculture.

Figure 16: Wet and dry season comparison north of Adi Ha

5 Statistical modeling of rainfall

To design a rainfall-based index insurance contract to protect farmers against drought-related crop losses, it is important to understand the properties of the daily rainfall process in the region that will be covered by the contract. In addition, it will be essential to go beyond the simple diagnostics we have performed thus far on remote sensing and rainfall to develop formal statistical processes for evaluation of the ARC and other remote sensing datasets. We provide preliminary results from a new model model daily rainfall we are working on in the technical annex associated with this report (http://iri.columbia.edu/publications/id=1004).

This model extends our previous efforts as a first step towards comparing and integrating information from multiple rainfall data sources. The end goal is to arrive at a formal statistical methodology that will systematically compare, evaluate, and integrate information on remote sensing of rainfall, ground-based data measurements, and other data sets.

The goal is to allow data sets to provide information on the existence of potential droughts that were observed in multiple data sets, including those that extend further back in time. In addition, the modeling is intended to allow the level of agreement between data sources to be quantified, which will be important when determining when an index can be transferred from one data source to another. The analysis presented in this section is at a midpoint in this process, and if resources continue to be obtained, we intend to further develop these methods and then package them into tools for contract design and evaluation.

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