PROJECT SUMMARY

INDEX BASED LIVESTOCK INSURANCE FOR NORTHERN KENYA'S ARID AND SEMI-ARID LANDS: THE MARSABIT PILOT

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In Kenya's arid and semi arid lands (ASALs), drought is the most pervasive hazard, natural or otherwise, encountered by households on a widespread level. This is especially true for northern Kenya, where more than 3 million pastoralist households are regularly hit by increasingly severe droughts. In the past 100 years, northern Kenya recorded 28 major droughts, 4 of which occurred in the last 10 years. For livelihoods that rely solely or partly on livestock, the resulting high livestock mortality rate has devastating effects, rendering these pastoralists amongst the most vulnerable populations in Kenya. As the consequences of climate change unfold, the link between drought risk, vulnerability and poverty becomes significantly stronger.

Index-based insurance products represent a promising and exciting innovation for managing the climate related risks that vulnerable households face. The creation of insurance markets for events whose likelihood of occurrence can be precisely calculated and associated to a well defined index is increasingly being championed as a way to make the benefits of insurance available to the poor. Over the past year, the International Livestock Research Institute (ILRI), in collaboration with its partners at Cornell University, the BASIS Research Program at the University of Wisconsin-Madison, and Syracuse University, has pursued a substantial research program aimed at designing, developing and implementing market-mediated index-based insurance products to protect livestock keepers - particularly in the drought prone ASALs – from drought-related asset losses.[1]

Much of the initial preparatory phase, which included an extensive program of field work and stakeholder consultation, is now complete. An index-based livestock insurance (IBLI) contract has also been modeled, priced, and is ready for implementation. The remainder of this note defines the key features of a general index-based contract, highlighting the specifics of our IBLI contract, and lays out a pilot strategy to test its effectiveness and commercial sustainability.

1. Advantages and Limitations of Index Based Insurance

Like any insurance product, index-based insurance aims to compensate clients in the event of a loss. Unlike traditional insurance, which makes payouts based on case-by-case assessments of individual clients' loss realizations, index-based insurance pays policy holders based on an external indicator that triggers payment to all insured clients within a geographically-defined space. For index insurance to work, there must be a suitable indicator variable (the index) that is highly correlated with the insured event. Using a data source that is promptly, reliably, and inexpensively available (and not manipulable by either the insurer or the insured), an index insurance contract makes the agreed indemnity payment to insured beneficiaries whenever the data source indicates that the index reaches the "strike point," or insurance activation level.

For example, if one is insuring against livestock mortality, then rainfall or forage availability may be suitable indicators if drought or a shortage of forage, or a combination of the two, often result in above-normal livestock mortality. One could then write an insurance contract based on (some stastistically-specified function of) a rainfall or forage indicator to protect against specified levels of aggregate livestock losses. The contract would specify its geographical reach, temporal (or seasonal) coverage, the strike level, the relevant premium and payment terms.

[1] This work would not have been possible without the generous financial support of the USAID and the World Bank.

An index-based insurance product has significant advantages over traditional insurance. Traditional insurance requires that the insurer monitor the activities of their clients and verify the truth of their claims. For relatively small clients in infrastructure-deficient environments like the northern Kenyan ASALs, the costs of such monitoring are often prohibitive. With index-based insurance products, all one has to do is monitor the index, thereby sharply reducing costs. Furthermore, by using an index based on variables that cannot be influenced by any insuree's behaviour, index-based insurance products overcome the key problems with traditional insurance contracts of an individual's experience: that more (less) risk-prone individuals will self-select into (out of) the contract and that insured individuals have an incentive to take on added risk – phenomena known as "adverse selection" and "moral hazard," respectively.

These gains from index-based insurance come at the cost of "basis risk", which refers to the imperfect correlation between an insuree's potential loss experience and the behaviour of the underlying index on which the insurance product payout is based. Individuals can suffer losses specific to them but fail to receive a payout because the index does not trigger. On the other hand, lucky individuals may receive indemnity payments that surpass the value of their losses. While this problem cannot be completely eliminated, we have carefully designed the IBLI contract to minimize basis risk and therefore to maximize its value to the insured population.

2. Overview of Index-Based Livestock Insurance (IBLI) for the ASAL

2.1 Economic and Social Returns to IBLI

The economic and social returns to an effective program that insures pastoral and agro-pastoral population against drought-induced livestock losses can be substantial as it can:

- *Stabilize Asset Accumulation and Enhance Economic Growth.* Insuring assets against catastrophic loss addressed the high risk of investment in such environments. This should improve incentives for households to build their asset base and climb out of poverty.

- *Crowd-in Finance for Ancillary Investment and Growth.* The negative effect of a risky environment on investment incentives is not limited to households. Private creditors presently unwilling to lend for such ventures due to the risk associated with big shocks like drought might become willing to lend if the assets that secure their loans could be insured. Insurance can thereby "crowd-in" much-needed credit for enterprises in the region without leaving poor ASAL residents excessively vulnerable to losing assets when nature fails them.

- *Stem the Downward Spiral of Vulnerable Households into Poverty.* Because it provides indemnity payments after a shock, livestock insurance should help stem the collapse of vulnerable-but-presently-non-poor households into the ranks of the poor following a drought (or related crisis) due to irreversible losses from which they do not recover.

2.2 IBLI Design and Implementation Challenges

Despite the contractual advantages of an index based insurance product as well as the potential economic and social benefits that could arise, four major challenges confront the creation of an IBLI contract.

- *High quality data* are required to accurately design and price insurance contracts and determine when payouts should be made.

- *Design of an optimal insurance index* that to the maximum extent possible reduces the risk borne by the target population so that the value and potential demand for the product are high;

- *Effective demand* for IBLI insurance among a target clientele largely unfamiliar with insurance in general and index-based agricultural insurance in particular; and,

- *Cost-effective ways of delivering* IBLI insurance to small and medium scale producers in remote locations.

We now briefly describe solutions to each of these problems. It is important to emphasize that in designing the insurance contract our objective is to catalyze a commercially sustainable market to deliver the product. Our preliminary investigations lead us to believe that a market-mediated product is indeed feasible and would be the most effective delivery method. However, it is worth noting that the genesis of our intent to design IBLI was our desire to manage the risks faced by vulnerable pastoral and agro-pastoral populations and provide them with a productive safety net that can be implemented as a government or donor-driven social protection program. Nevertheless, these two objectives are not mutually exclusive and would utilize both the same contract and delivery channel. Where governments want to utilize IBLI as a productive safety net, they could simply subsidize the premiums for recipient households.

2.3 Satellite Imagery Solves the IBLI Data Problem

The country of Mongolia currently has an IBLI contract for pastoralists that is based on directly measured livestock mortality. While there are both advantages and disadvantages[2] to the use of directly measured livestock mortality data, it is not a feasible option in Kenya. While some data on herd mortality in northern Kenya is available, coverage is spotty and inadequate to write a contract. To devise a contract, we therefore had to find a measure that is (1) highly correlated with local livestock mortality; (2) reliably and cheaply available for a wide range of locations; and, (3) historically available to allow pricing of product.

The Normalized Difference Vegetation Index (NDVI) meets these conditions. Constructed from data remotely sensed from satellites, NDVI is an indicator of the level of photosynthetic activity in the vegetation observed in a given location. As livestock in pastoral production systems depend almost entirely on available forage for nutrition, NDVI serves as a strong indicator of the vegetation available for livestock to consume. The NDVI data are available at the resolution of $8.0\times$ 8.0 km. Since the late 1980s, the United States' NASA and NOAA have used AVHRR data[3] to

[2] The biggest disadvantage that has been noted in Mongolia is the reliability of the reported mortality rate, since large insurance payoffs depend on the number that is reported by the government.

[3] NDVI is derived from data collected by National Oceanic and Atmospheric Administration (NOAA) satellites, and processed by the Global Inventory Monitoring and Modeling Studies group (GIMMS) at the National Aeronautical and Space Administration (NASA).The NOAA-Advanced Very High Resolution Radiometer (AVHRR) collects the data used to produce NDVI. Values of NDVI for vegetated land generally range from about 0.1 to 0.7, with values greater than 0.5 indicating dense vegetation.

produce dekadal (10-day) composite NDVI images of Africa, and have built a valuable archive of these data from June 1981 to present, which are available in real time and free of charge.[4]

2.4 Using NDVI to Create a Livelihood-optimized IBLI

While NDVI has properties that make it reliable as the basis for an insurable index, it must also have value for the insured. In other words, NDVI data has to predict livestock mortality rates reasonably precisely. We used household-level livestock mortality data collected monthly since 2000 in various communities in Kenya's ASAL districts by the Government of Kenya's Arid Lands Resource Management Project (ALRMP) and by the USAID-funded Pastoral Risk Management (PARIMA) Project to statistically estimate the relationship between NDVI measures and observed livestock mortality. Our current contract is based on Marsabit District, the focus for the pilot. As detailed in the Statistical Annex below, we combined those herd history data to create an optimal insurance index defined as the function of the NDVI data that is simple, replicable, commercially implementable and highly correlated with the herd mortality data so that it provides the maximium possible insurance value to the pastoralist population.

2.5 Insurance Simulation Games to Create Informed Effective Demand for IBLI

Experience with other index-insurance pilots has shown that a carefully designed program to educate potential clients about these products is a necessary prerequisite to both initial uptake and continued engagement with insurance. Index-insurance products are complex to understand, especially for populations in remote rural areas with minimal previous experience with formal insurance products and low literacy levels. In order to generate sufficient demand and ensure that the risk-management benefits of insurance effectively serve IBLI clients, they must clearly understand the value of IBLI and, in particular, how the product works.

In order to design an extension tool that adequately captures the complexities of the IBLI product and communicates the key features of the contract terms, we took a cue from the growing field of experimental economics. Experimental games, the main tool of this field, offer methods by which complex concepts can be distilled and taught in a relatively simple manner. Dynamic decisions or processes can be easily repeated during game play to mirror the consequences of alternative choices and to elicit behavioral responses that could otherwise take years to understand.

Though the games are both time- and resource-intensive, participants come away with quite a clear understanding of the key aspects of an index insurance product: That they would have to pay for insurance before the season began and for each season of expected coverage; that index insurance would not cover non-drought related losses; that indemnity payments were triggered as a result of covariate climate events (droughts); that if a drought did not trigger payments, the premium was not returned.[5]

[4] Further details about NDVI are available at http://earlywarning.usgs.gov/adds/readme.php?symbol=nd.

[5] Additional details on this and similar games to improve financial literacy and understand index insurance can be found in the BASIS Brief "Insuring The Never Before Insured: Explaining Index Insurance Through Financial Education Games", available at http://www.basis.wisc.edu/live/amabrief08-07.pdf.

In our preparatory phase, we played the game with over 200 participants in 5 sample communities across Marsabit District. As both an extension and marketing tool, it would be hard to beat such a game. Not only did participants seem to come to understand the product, but they also appeared to enjoy the game and there was animated discussion throughout the day. Most of them grew excited about the product and appear eager to have it introduced. While resource constraints will likely limit the reach of such games across the target marketing area, games can be played among opinion leaders expected to diffuse the information and can also be summarized in video documentaries or the like that can be more cost-effectively shown in various community educational fora.

2.6 A Cost-Effective Implementation Model for IBLI

The pilot district, Marsabit, is a remote, sparsely populated and relatively infrastructure deficient area. As such, in thinking through product and implementation, one cannot ignore the challenges that may arise in targeting clients, accepting premiums, and making indemnity payments within a system that generates enough confidence to allow for active market mediation. Insurance companies would need to develop a cost-effective administrative infrastructure and identify the agents necessary to conduct transactions on their behalf as well as partners with local experience to help facilitate the requisite community interaction.

Fortunately, a substantial social protection program, the Hunger Safety Net Program (HSNP), funded by the United Kingdom's DfID, is rolling out in four of Kenya's poorest districts in early 2009. Within a year, and for the first four-year phase of its ten-year expected duration, the HSNP plans to deliver regular cash transfers to 60,000 households spread across Mandera, Marsabit, Turkana and Wajir Districts. This is a huge task requiring a well-designed delivery channel with a wide network across these regions.

The Financial Sector Deepening Trust (FSD), in conjunction with Equity Bank, have been working on just such a delivery channel and have the responsibility of creating the necessary information, communications and financial infrastructure needed to support the HSNP. Equity Bank has been contracted to open over 150 new Points of Sale (PoS) across these regions that will be able to facilitate and provide the HSNP cash transfers to recipient households. Using new hi-tech wireless portable devices within a sophisticated computing system, these PoS devices can be easily configured to accept premiums for certain insurance contracts and register indemnity payments when necessary. Discussions are underway to ensure that FSD and Equity Bank offer index insurance contracts on the back of their HSNP delivery chain. Where we would like to offer the product in Marsabit communities not selected to receive HSNP cash transfers, it would be relatively easy to extend the PoS network to these areas.

2.7 Integrated Research Design to Measure the Impacts of IBLI

The IBLI insurance scheme will initially be piloted in one district so that implementation problems can be fully resolved and its impacts reliably evaluated. To determine these impacts, random samples of households in both selected (treatment) and non-selected (control) sub-locations will be interviewed to source the information needed for the evaluation. In order to get a sense of the optimal pricing of the IBLI product, as well as test the hypothesis that subsidizing insurance premiums can serve as a cost-effective social protection program, we aim to induce price variation amongst a subset of the study sample. We plan to do this by splitting households into 3 wealth classes; Households deemed to be chronically poor (Category 1), vulnerable households teetering on the edge of poverty (Category 2), and better off households not in much danger of falling into poverty in the absence of a major shock (Category 3).

To explore the amount of subsidy needed to induce purchase of IBLI, individual households will be randomly allocated discount coupons ranging between 10% and 90% of the marketed premium. Our research budget will cover the cost of these coupons; the insurer(s) will receive full payment of all insurance premiums. Category 3 households will receive no coupons. We propose an *average* premium discount of 50% for Category 2 recipients of the coupons, and 75% for Category 1 households. A rigorous impact assessment of this type will provide important information on pricing and uptake to the private sector and also allow us to test the validity of the expected effects enumerated in section 2.1. The research offers an important learning opportunity not only for the private sector, but also for governments and the development community worldwide.

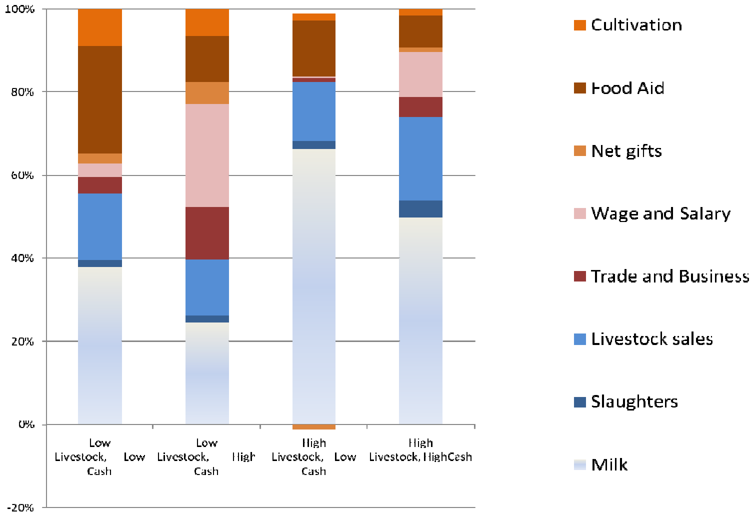
3. The Marsabit IBLI Pilot

3.1 Overview of the Livestock Economy in Marsabit District

Northern Kenya's climate is generally characterized by bimodal rainfall with short rains falling October – December, followed by a short dry period from January-February, and long rains in March-May, followed by a long dry season from June-September. Pastoralists rely on both rains for water and pasture for their animals, as well as occasional dryland cropping. Pastoralism in the arid and semi-arid areas of northern Kenya is nomadic in nature, where herders commonly adapt to spatiotemporal variability in forage and water availability through herd migration.

Livestock represent the key source of livelihood across most ASAL households. As Figure 1 shows, when households are split across four categories – high and low cash income and high and low livestock holdings (where the threshold for high/low is determined by median value), only the low livestock, high cash households obtain less that 50% of their income from livestock.

Figure 1: Income Sources By Livelihood Grouping



Source: PARIMA 2000-2002 data

The danger is that livestock face considerable mortality risk, rendering pastoralist households vulnerable to herd mortality shocks. Among these, drought is by far the greatest cause of mortality (Figure 2A) and drought-related deaths largely occur during severe shocks, as during the rain failure of2000 (Figure 2B). IBLI is designed to for precisely these instances of considerable loss. During times of relative normalcy, mortality arises relatively randomly due to non-drought related mortality causes such as diseases and predators, which IBLI will not cover.

Figure 2A: Causes of Livestock Mortality

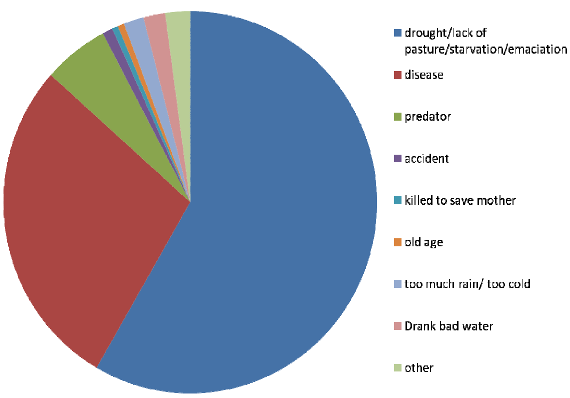
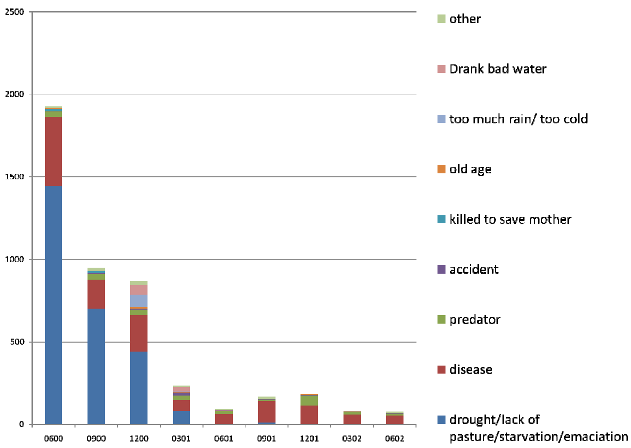


Figure 2B: Causes and Relative Number of Livestock Losses by Season

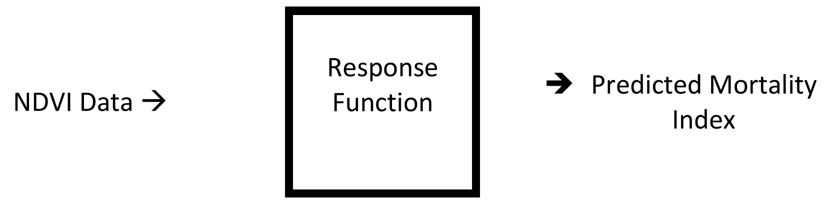


Source: PARIMA 2000-2002 data

3.2 Contract terms

Following the strategy laid out in the prior section, we have designed an IBLI contract for Marsabit District. At the core of the contract is a response function that translates observed NDVI data into a statistically reliable predictor of livestock mortality, as depicted heuristically in Figure 3.

Figure 3: Translating NDVI Data Into Estimated Livestock Mortality



For example, consider the Gudere family in Kargi who purchase 10 livestock units of IBLI insurance for the 2009 long rain/long dry season. The IBLI contract stipulates two key parameters: (1) The value that will be paid for each livestock unit that is later estimated to have been lost; and, (2) The "strike point," meaning the index level at which the insurance is activated and payouts begin. For this example, assume that the contractually stipulated livestock value is KSh10,000 per livestock unit and that the stipulated strike point is a predicted mortality rate of 15%.

So how will this insurance work? We would first obtain the 2009 long rain/long dry NDVI data for the 8 km^2 blocks that surround Kargi and feed those data into the response function, generating the predicted mortality index. For example, let's imagine that the predicted mortality rate or index for the Kargi area is 25%. This 25% mortality index is then compared to the contractually stipulated strike point of 15%. In this example, the Gudere family would receive compensation for 10% (=25%-15%) of their covered herd of 10 livestock units. They would thus receive a payment of KSh10,000 (= 10% x 10 livestock units X 10,000 value per livestock unit). All the Gudere's insured neighbors in Kargi would receive compensation at the same predicted rate of 10% of their insured herds. Those who bought no insurance would receive no indemnity payment.

Consider the insured Haro family that lives in Kalacha that also buys IBLI insurance for 10 livestock units in 2009 long rain/long dry. Suppose that the NDVI data for Kalacha are even less favorable than those for Kargi and the response predicts a livestock mortality rate for Kalacha of 35%. In this case, the Haro family (and all their insured neighbors) would receive compensation for 20% of their insured herd, with the Haros receiving KSh20,000.

As these examples make clear, the response function that translates NDVI data into predicted mortality rates is an important part of the IBLI contract. As explained in the Statistical Annex (Annex 1), we identified statistically the response function that best predicts livestock mortality in Marsabit District as a function of NDVI. Our analysis revealed that it is necessary to divide Marsabit district into two zones or clusters, each distinguished by its own response function that reflects the different herd compositions and agro-ecological realities of the two clusters: the

Laisamis Cluster and the Chalbi Cluster (see the map in Annex 1). Chalbi cluster is drier and its herds have a higher fraction of camels and smallstock while in Laisamis cattle dominate.[6]

With the response function in hand, we use the historical NDVI data to calculate the probability of payouts under different insurance contracts. This lets us calculate the "pure" or "actuarially fair" premium associated with each contract.[7] As indicated above, a key contract parameter is the strike point or insurance activation level. Payments will occur more frequently and be larger under a low strike point (for example a 10% predicted mortality level) than under a high strike point contract (say 20%). Therefore, the low strike point contract will naturally cost more.

Table 1 shows the pure premium rates estimated for the Chalbi and Laisamis clusters. Returning to the example above with a 15% strike point, the pure premiums for the Guderes and Haros would be KSh5,000 for a 10 unit herd or KSh500 per insured animal. A family in Laisamis would pay a bit less, KSh300 per insured livestock unit.

Table 1: Calculated Premiums for Unconditional Contracts across Strike

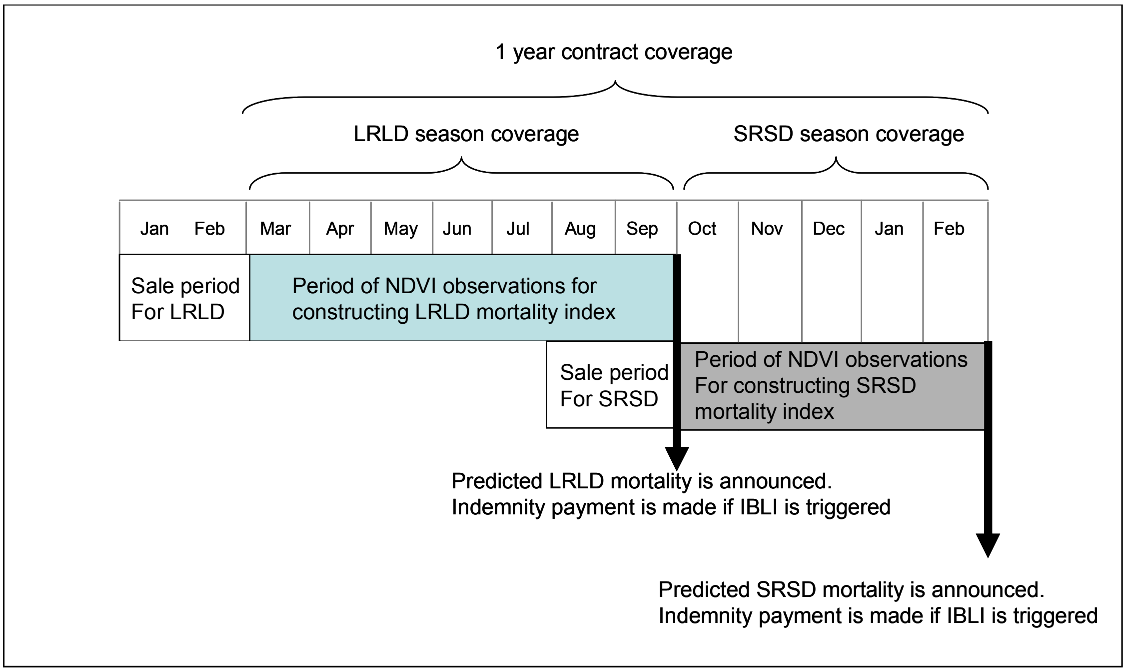
Cluster/Contract	Premium Rate (% of insured value)			
	10% Strike point	*15% Strike Point*	*20% Strike Point*	*25% Point*
Chalbi Cluster	**9%**	**5%**	**3%**	**1%**
Laisamis Cluster	**5%**	**3%**	**1%**	**1%**

Temporal coverage of the contract is likewise an important feature the contract must specify. Unlike conventional insurance products, index insurance is only sold within a specific window of time – before any signal emerges as to how the insured climate will unfold. We present a seasonal contract (each encompassing a rainy and dry season pair), with the contracts sold before the rainy period of each season and assessed at the end of the dry period to determine whether payouts are to be made (See Figure 4 below). It is also possible to design a one-year contract that has two potential trigger points per year (one at the end of each dry season).

[6] While we model the contracts separately, insurers might charge the same premium for both Chalbi and Laisamis contracts. While such a strategy of cross-subsidization could lead to spatial adverse selection, it could also be simpler and limit complaints from those clients asked to pay higher premiums.

[7] The pure or actuarially fair premium is the premium level which just equals the expected or average payout. Market based insurance is sold at a mark-up or loading above and beyond the pure premium in order to cover the administrative and other costs of selling and delivering the insurance.

Figure 4: Temporal structure of IBLI contract



3.3 Pilot Timeline

We expect to pilot a bona fide contract for the SRSD (short rain short dry) period starting in October 2009. Having largely completed the contract design, begun acquainting target populations with the product through experimental IBLI games, and with necessary conversations with key stakeholders already well along, we are optimistic that a pilot is possible. Below we set out a timeline of activities required to prepare for the pilot.

February – May 2009
- Sign piloting agreement with insurance company (or consortium of companies) and re-insurance company.
- Set contract terms and revise contract accordingly
- Complete delivery channel agreements
- Receive requisite approval from regulators

June – August 2009
- Conduct baseline study of target population in pilot and control communities.

August – September 2009
- Conduct IBLI games in pilot sites as a product familiarization tool
- SRSD season (October-February) insurance sold in pilot communities (along with discount coupons for selected recipients in eligible sub-populations).

January – February 2010
- Conduct further IBLI games in pilot sites as a product familiarization tool

- LRLD season (March-September) insurance sold in pilot communities (along with discount coupons for selected recipients in eligible sub-populations).

March 2010
- Livestock mortality index announced based on NDVI measures during SRSD seasons.
- Insurers make any contractually-required indemnity payments based on index.

4. Looking Forward

4.1 Next Steps

As we proceed toward piloting, the next key milestone involves a stakeholder workshop to be held on ILRI's Nairobi campus on Monday, March 16th, 2009. The workshop will be conducted by the project's technical team and aims to build awareness and disseminate information on the project, the design of the contracts and pricing, as well as to generate concrete interest and build momentum behind the pilot as we begin to finalize the necessary agreements.

Workshop participants will include insurance and re-insurance companies with a demonstrated interest in playing a role in the pilot. Financial service providers, delivery channel partners, key members of the relevant government ministries, including regulatory bodies such as the Insurance Regulatory Agency of Kenya and the Central Bank of Kenya will also be invited. NGOs, CBOs and client representatives such as the Kenya Livestock Marketing Council and the Pastoral Development Network of Kenya, as well as donors and development agencies such as USAID, DfID, the World Bank and FSD will also be present.

Soon after the workshop, we expect to have signed agreements with insurance companies, and other key implementing partners required for the pilot's success. We also expect to have secured regulatory clearance. We shall thereafter proceed with the activities necessary to begin selling contracts in August and September. This will include a substantial extension effort based on the insurance games explained above as well as conducting the M&E baseline amongst a study sub-set of the target clientele.

For **further information** on the conference and on the project in general, please visit the **conference webpage at http://www.ilri.org/livestockinsurance**. The webpage will provide a detailed schedule of workshop events and will also include access to key project documents including the technical paper *Designing Index-Based Livestock Insurance For Managing Drought-related Livestock Asset Risk in Northern Kenya* by Chantarat et al., 2008, that provides detail on modeling specification, contract design and coverage terms. Briefs explaining game design, concept notes explaining proposed M&E strategy and the like are also available on this websites as are other relevant references of a more general nature.

Statistical Annex: Methodology for Designing and Pricing IBLI in Marsabit District

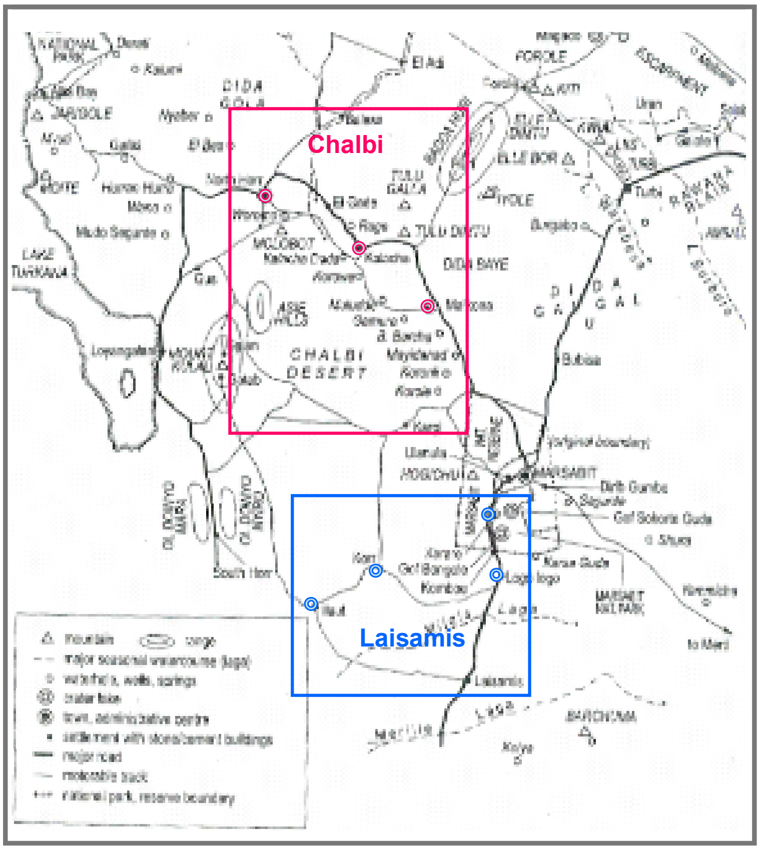
The following steps were taken to characterize and price an IBLI product in Marsabit[8]:

1. Divide Marsabit District into 2 clusters

We divide Marsabit into 2 distinct geographic zones (Figure A1) based on statistical cluster analysis, which bundles locations with similar characteristics, such as distribution of species within a herd, mortality rates and variables that may influence the predictive relationship between livestock mortality and NDVI.

- Chalbi cluster (3 locations: North Horr, Kalacha and Maikona)
- Laisamis cluster (4 locations: Karare, Logologo, Ngurunit, Korr)

Figure A1. Chalbi and Laisamis contract coverage clusters



2. Estimate the relationship between seasonal livestock mortality and NDVI

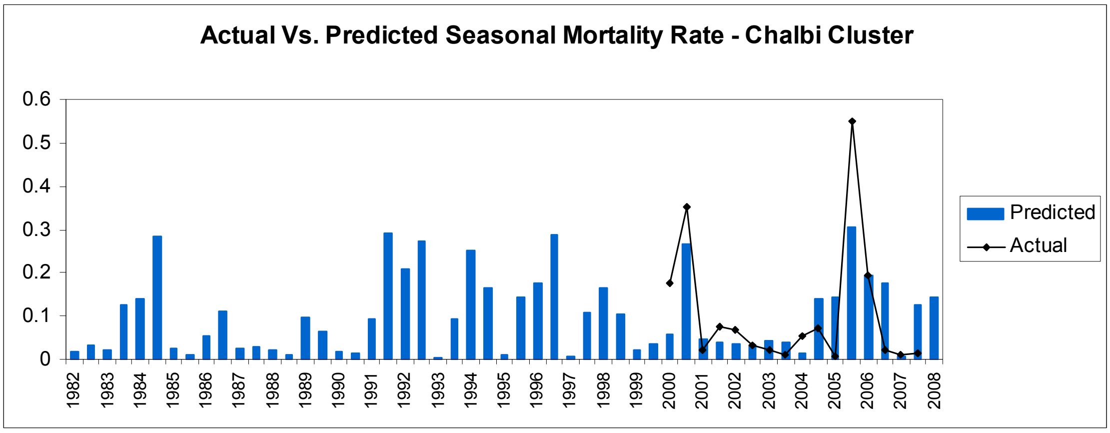
[8] For more details, see Chantarat, Mude, and Barrett (2008) "Designing Index-Based Livestock Insurance For Managing Drought-related Livestock Asset Risk in Northern Kenya" or contact Andrew Mude (a.mude@cgiar.com), Sommarat Chantarat (sc384@cornell.edu) or Chris Barrett (cbb2@cornell.edu).

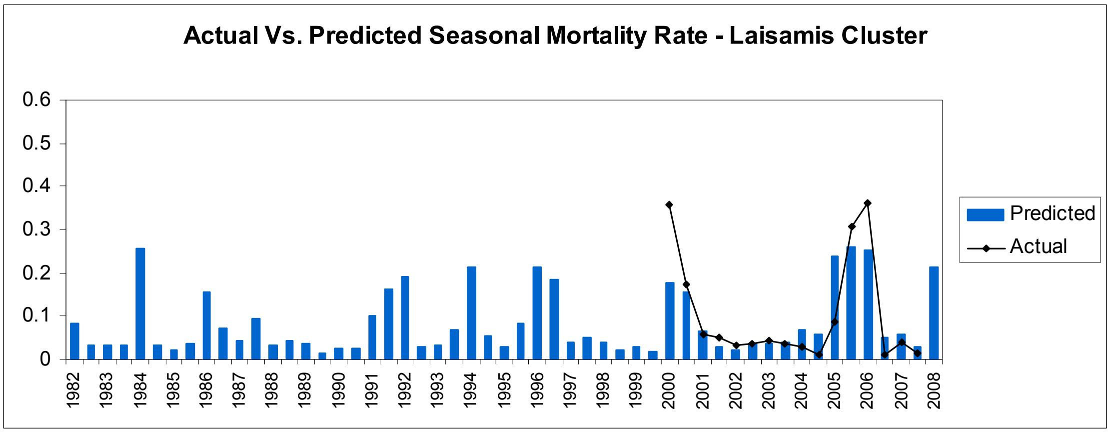
The predictive relationship between area averaged livestock mortality rate in location *l* in season *s*, M_{ls}, for each cluster is estimated as the following regime-switching regression model:

$$M_{ls} = M_g(ndvi) + \varepsilon_{gls} \quad \text{if good climate regime } (Czndvi\_pos_{ls} \geq 0)$$
$$M_{ls} = M_b(ndvi) + \varepsilon_{bls} \quad \text{if bad climate regime } (Czndvi\_pos_{ls} < 0)$$

where $ndvi$ represents the constructed explanatory variables based on NDVI, and ε_{ils} is the risk components not explained by climate (e.g., due to disease outbreak, livestock raiding, wildlife predators, etc.) in the bad (i=b) and good (i=g) regimes. The regimes are defined by the accumulated deviation of value of NDVI from its long-term average from the last rainy season until the end of the current season ($Czndvi\_pos_{ls}$). We constructed the actual seasonal livestock mortality rates[9] based on 2000-2008 mortality data and NDVI-based mortality index based on 1982-2008 NDVI data for both LRLD and SRSD seasons (Figure A2).

Figure A2: Seasonal TLU Mortality Rates in Laisamis Cluster





3. Pricing IBLI contracts under the estimated statistical relationship

[9] We aggregate across livestock species using the tropical livestock unit (TLU) measure, where 1 TLU = 1 cattle = 0.7 camel = 10 goats or sheep.

We show only the simplest version of pricing the resulting contract. The actuarially fair premium rate per season per value of TLU livestock insured for location *l* in season *s* covering the loss event that the predicted area averaged mortality index $\hat{M}_{ls}$ is beyond the mortality strike of M_l^* can be written as:

$$p_{ls}\left(M_l^*\right) = E\left(Max\left(\hat{M}_{ls} - M_l^*, 0\right)\right)$$

where $E(\cdot)$ is the expectation operator over a distribution of NDVI based mortality index. Note that this actuarially fair (pure) premium rate does not include the amount insurance companies may add for covering transaction costs and risk (variance) of payouts. We report the estimated premium rates for contracts with various strikes for both clusters in Table 1.

Extensive background technical detail is available on the statistical development of the index, the calculation of pure premium rates and statistical evaluation of contract performance, both in terms of out-of-sample forecasting accuracy and in terms of household-level basis risk.