Assessing the value of index insurance for herders: comparing NDVI-based insurance products

Scope of work for Cornell University

November 2ndth, 2015

Funding Source: Global Action Network on Index Insurance grant, UC Davis.

Duration: January 1st, 2016-December 31st 2016 (12 months)

Contributors:

1. Andrew Mude – ILRI
2. Anton Vrieling - University of Twente
3. Chris Barrett - Cornell University (PI)
4. Clement Atzberger - Universität für Bodenkultur Wien
5. Francesco Fava – ILRI
6. Michele Meroni –JRC European Commission
7. Nathan Jensen - Cornell University
8. Quentin Stoeffler - UC Davis

Main outputs:

1) An academic article to be published in the *Journal of Risk and Insurance* or a similar scientific journal.
2) Presentation comparing the two data sources and derived indices and making recommendations for future social safety net programs in Kenya.
3) Groundwork for a more technical paper aimed at a remote sensing audience.

Project Summary:

The Index Based Livestock Insurance (IBLI) and the Hunger Safety Net Programme (HSNP) are among the most prominent social safety net programs in Kenya and in Sub-Saharan Africa. These programs have a common objective of protecting livelihoods from shocks, but they rely on very different logics and mechanisms, with possibly important consequences in terms of impact on pastoralists' wellbeing and productive investments (Carter & Janzen, 2015; Jensen, Barrett, & Mude, 2014b). Of particular interest for this research, both programs rely, in part, on normalized difference vegetation index (NDVI) based indices, but the precise NDVI data sources and the processing of the NDVI time series are quite different. In addition, the index on which the IBLI product is based has changed dramatically since IBLI launched in 2010, further highlighting the wide variety of index options available. This research will examine a range of drought-related indices based on data sources and parameters used by HSNP and IBLI, in order to determine which is most appropriate for an index insurance product that aims to protect households from drought related shocks. This research is of interest to the broad community of researchers and practitioners that use NDVI to monitor for a range of related shocks and is of immediate interest to the IBLI and HSNP programs as they scale up.

The IBLI product uses eMODIS data, which are NDVI time series from the Moderate Resolution Imaging Spectroradiometer instrument (MODIS) that are composited and filtered by the USGS and publicly available (with five weeks lag-time) at no charge. The current IBLI policies are based around the bimodal rainy/dry seasons in northern Kenya and make indemnity payments about one month after any season that triggers a payout. IBLI has recently developed a new index policy in hopes of offering a product that will work towards protecting, rather than replacing, assets. These asset protection products are based on an index that is temporally aggregated across a shorter time period, permitting earlier payout after drought events as compared to the former asset replacement products.

Phase II of HSNP includes an index-based mechanism for expanding coverage and increasing transfers during crisis periods. The HSNP index is developed from 16-day composites of NDVI data collected from Aqua and Terra satellites that is filtered using a modified version of the Whittaker smoother (Eilers, 2003) in near-real-time by Universität für Bodenkultur Wien (BOKU) to generate a vegetation condition index (VCI). The index is provided for a fee to Kenya's National Drought Monitoring Authority (NDMA), who then provide the data to HSNP. BOKU's NDVI filter uses a temporal filtering process that allows it to both provide NDVI forecasts and uncertainty estimates associated with the data, neither of which is available from eMODIS. Interestingly, the government of Kenya is currently implementing the Kenya Livestock Insurance Program (KLIP), an index insurance based social protection program that is based on the IBLI index rather than the index used by their own drought monitoring agency-NDMA.

While the development of multiple distinct NDVI-based forage indices risks confusing clients and beneficiaries, it offers a research opportunity to assess and compare the performance of a variety of indices as the base for index based livestock insurance. For example, a comparative analysis of eMODIS and BOKU data will provide insight into the costs and benefits of free vs. pay-for-service data filtering options.

Several metrics are now available and allow meaningful empirical comparisons between alternative policies. Indeed, ex-post assessments of product quality have started to focus on insurance value for clients, taking into account the real correlation between losses and insurance payments at the household level (D. Clarke, Mahul, Rao, & Verma, 2012; D. J. Clarke, 2011; Jensen et al., 2014a; Stoeffler, Barré, & Carter, 2015). The case of Kenya is particularly interesting because of: i) the substantial amount of top quality research conducted on pastoralists and IBLI products; ii) the opportunity to compare two real, implemented, index-based products in the same areas.

One of the main challenges for assessing these indices is the availability of household panels, necessary to measure shocks encountered by farmers or herders. Fortunately, these data are available in Northern Kenya for five consecutive years (10 IBLI seasons) and in neighboring areas of Southern Ethiopia for four consecutive years (8 IBLI seasons), allowing us to rigorously assess index insurance quality at the household level. Additional data will be required from the two institutions designing the NDVI-based indices, the University of Twente and the Universität für Bodenkultur Wien, to be able to retroactively associate (fictional) past insurance payouts and herders' real losses.

Once data are obtained, developing and assessing the value of a variety of insurance products for herders would be relatively straightforward given the previous work completed at Cornell and UC Davis. Measuring herder's losses would be based on the methods of Jensen et al. (2014a). Then, comparing insurance products can also build on the work from Jensen et al. (2014a) and be expanded to include indices designed specifically to measure index insurance value for households (Stoeffler, Barré & Carter, 2015). The results can inform policy choices in Kenya and Ethiopia, and pave the way for future assessment of index insurance value in order to design appropriate insurance products for herders and farmers.

The research proposed here has been divided into two phases. Phase 1 of this work will examine the impact of two important index and insurance policy parameters (each with two options) on the quality of the insurance products. Those two parameters are as follows.

Phase 1:

1. **Raw NDVI data filtering**: Filter-based noise removal is the first step to using MODIS NDVI data. We will examine and compare eMODIS (*NDVI_eMODIS*) and BOKU (*NDVI_BOKU*) based NDVI indices. Although timeliness is one potentially important advantage of the BOKU data, this Phase 1 analysis will focus on accuracy rather than timeliness. However, we hope to extend our analysis to include the potential benefits of timeliness in Phase 2.
2. **Aggregation**: The initial IBLI-Marsabit product first normalized (Z-score) the NDVI data at the pixel level, then averaged it across index divisions, and finally cumulated across the IBLI season for each index division. We call this a *CZ* product (e.g. z-scoring followed by cumulation). For these types of indices, there is a debate in the remote sensing community if it is better instead to first cumulate data across the index area and across time, and normalize last. We call this a *ZC* product. IBLI has recently switched from the *CZ* to the *ZC* index, but there has yet to be a local analysis to assess the gains, if any, of the change of method. We will examine and compare *CZ* and *ZC* type indices.

The resulting four indices (*CZ_NDVI_eMODIS, ZC_ NDVI_eMODIS, CZ_ NDVI_BOKU, ZC_ NDVI_BOKU*) will be used to develop hypothetical insurance policies for Kenya and Ethiopia using parameters from the asset replacement products available in Marsabit in 2012-2014 and in Ethiopia from 2012-2015. We will then backcast indemnity payments for the period covered by the household surveys and calculate actuarial premium payments. Index quality measures similar to that described in Stoeffler, Barré & Carter (2015) will be used to assess their relative value to the customers.

Upon completion of Phase 1, we anticipate examining additional parameters of interest. A discussion among the researchers involved in this study have identified three potential candidates, but the scope of this work is neither restricted to those three nor does it necessarily include them. Engaging in any of the research described in Phase 2 is optional and will be decided by the research team once Phase 1 is complete.

Phase 2 (optional):

1. **Alternative indices:** In contrast to IBLI's use of a z-score NDVI based index, HSNP uses a VCI index that linearly scales NDVI values by the difference between minimum and maximum values ($VCI = \frac{NDVI - NDVI_{min}}{NDVI_{max} - NDVI_{min}}$). Similar to the discussion on aggregation above, the VCI scaling can be performed at the pixel level, and then aggregated over space or visa-versa. In addition, there are other indices, such as the Vegetation Productivity Indicator (VPI), that are available and may be more accurate than the z-score based indices. Considering the growing importance of remotely sensed data in disaster monitoring and resource allocation, and plethora of available

indices, determining which of these indices tracks livestock losses best would be an important contribution.

2. **Indemnity schedule**: The initial IBLI product made indemnity payments about one month after the end of a standardized set of bimodal wet and dry seasons, presumably after the insured livestock perished. Vrieling et al. (2015) used phenological analysis of NDVI time series to better determine the period when forage develops and furthermore showed that the end of the forage development season index value can reliably (> 90 percent of the interannual variability) be predicted before the end of the season, together resulting in a 1-3 months earlier index calculation as compared to the asset replacement product. This discovery has led the development of an asset protection insurance product that makes indemnity payments before each season's end in hopes that the indemnity can be used, in part, to increase livestock survival rates and thereby generate greater value for policyholders. This analysis will extend the work by Vrieling et al. (2015) to determine if an asset protection product performs as well as the asset replacement product with respect to tracking livestock mortality rates, and what level of induced increase in survival would be necessary to make the asset protection (i.e., earlier payout) contract better value per unit premium cost than the established asset replacement product.
3. **Timeliness of data**: The USGS filtering process delays the delivery of filtered eMODIS data by one month. Such delays can be quite costly for insured households during and after shocks. BOKU provides a real-time filtering for its VCI data. This analysis will investigate the possible benefit for policyholders receiving payouts within shorter delays. The above work on asset protection vs. asset replacement will also be done using BOKU's VCI in order to determine the value of earlier data in both cases.

Summary of the tasks: Phase 1

1) Develop indemnity schedules for comparison
    a. Obtain historic (2001-2015[1]) filtered NDVI data from University of Twente and BOKU for Kenya and Ethiopia.[2] For each dataset (eMODIS and BOKU) and each country, we will need a dataset generated by normalizing first (z-score) and cumulating second, and a dataset generated by cumulating first and z-scoring second. Index regions are defined to be identical to the 2012 IBLI products. Index seasons are defined by the 2012 IBLI products and include 2012-2015 in Ethiopia and 2010-2015 in Kenya.
    b. Develop index policies from the two indices.
    (2 filtering processes × 2 aggregation approaches × 2 countries=8 total policies)
    c. Simulate season-location indemnity payments and actuarially fair premium rates.
2) Compute monthly herd size and seasonal loss rates for herders from IBLI datasets in Ethiopia and Kenya.
3) Assess the quality of the indices.

[1] This is the longest series that both processes can easily produce.
[2] See Vrieling et al., (2014) for information on the variety and characteristics of available NDVI signal data. In this case, both data sets use MODIS for their signal data and filtering will be done as though it is real-time.

References

Atzberger, C., & Luminari, L. (2015). *Satellite-based drought monitoring in Kenya in an operational setting*. Paper presented at the IBLI workshop, 9-11 June 2015, Nairobi.

Carter, M. R., & Janzen, S. (2015). Social Protection in the Face of Climate Change: Targeting Principles and Financing Mechanisms.

Clarke, D., Mahul, O., Rao, K. N., & Verma, N. (2012). Weather based crop insurance in India. *World Bank Policy Research Working Paper*(5985).

Clarke, D. J. (2011). *A theory of rational demand for index insurance*: Department of Economics, University of Oxford.

Eilers, P. H. (2003). A perfect smoother. *Analytical chemistry*, *75*(14), 3631-3636.

Jensen, N. D., Barrett, C. B., & Mude, A. (2014a). Basis risk and the welfare gains from index insurance: Evidence from northern Kenya. *Available at SSRN 2505764*.

Jensen, N. D., Barrett, C. B., & Mude, A. (2014b). Index Insurance and Cash Transfers: A Comparative Analysis from Northern Kenya. *Available at SSRN 2547660*.

Stoeffler, Q., Barré, T., & Carter, M. (2015). Measuring Index Insurance Quality *I4 Brief*: BASIS.

Vrieling, A., Meroni, M., Mude, A.G., Chantarat, S., Ummenhofer, C.C., & de Bie, C.A.J.M. (2015). Early assessment of seasonal forage availability for mitigating the impact of drought on East African pastoralists. *Under review*

Vrieling, A., Meroni, M., Shee, A., Mude, A. G., Woodard, J., de Bie, C.A.J.M., & Rembold, F. (2014). Historical extension of operational NDVI products for livestock insurance in Kenya. *International Journal of Applied Earth Observation and Geoinformation, 28*, 238-251.