

# Workshop: Technical Issues in Index Insurance

## Topic 8: Remote Sensing - Vegetation

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### Index Insurance and Remote Sensing

Index insurance is a financial product contracted on an index used as a surrogate for yield failure instead of being contracted directly on yield loss. The index is usually based on rainfall, vegetation status or other types of surrogates for crop production (*e.g.* evapotranspiration, water requirement satisfaction index). Retrieval of rainfall and vegetation indices from remotely sensed data has been extensively studied and operational products have been available for more than 25 years. Rainfall and vegetation products derived from remotely-sensed data provide independent measurement across large areas around the world and are available in near real-time. Thanks to the development of the internet, satellite images and derived products are becoming easier to access and their precision regarding spatial resolution has reached new levels at sub-meter precision. This easy access and the capacity to monitor crops around the world with independent measurements are attractive features upon which to base the development of new insurance products.

### State of the Art

The primary index for monitoring vegetation status as a surrogate for pasture and crop production is the Normalized Differential Vegetation Index (NDVI), a satellite derived indicator of the amount and vigor of

vegetation. The magnitude of NDVI is related to the level of photosynthetic activity in the observed vegetation. In general, higher values of NDVI indicate greater vigor and amounts of vegetation (Tucker, 1985).

Index insurance contracts based on vegetation are generally designed to insure against a decline in NDVI over a designated area (called a grid) and are primarily intended for use by producers whose crop production tends to follow the average vegetation patterns for that designated area (Rasmussen, 1997). Losses are calculated using the vegetation index and producers are indemnified based on the deviation from normal within the grid and index interval(s) selected.

For pastures, monitoring vegetation vigor and biomass during the growing season provides a good estimation of what the final pasture production will be. This assumption is based on statistical correlations found between vegetation greenness and forage production (Fuller, 1998). Vegetation greenness, however, does not directly predict forage production. For crop production such as maize, soybean, millet, and wheat, the relationship between vegetation vigor/biomass during the growing season and final crop production (in terms of seeds produced) is not as simple. Although the vigor and biomass can be used as a proxy for final seed

production in some cases (Fuller, 1998, Fischer, 1994, Maselli *et al.*, 1993, Rasmussen, 1992), the exact relation of NDVI to crop yield depends on a range of factors (*e.g.* nutrients, solar radiation, water stress during critical stages such germination, growing and flowering).

NDVI decrease is often used as a surrogate for monitoring stress due to drought. Because drought is typically a spatially coherent phenomenon, NDVI datasets with a spatial resolution (grid) of 1km to 8km are generally considered adequate to capture the evolution of drought episodes. In many index insurance applications, payouts are based on an individual met station. NDVI may be helpful in quantifying the distance from the met station for which the contract is useful. It may also be useful in the case of a relative new met station where NDVI might provide information on past droughts. In regions where crops are grown on a large industrial scale such as the USA and Canada, NDVI can provide a measure of crop health directly. In regions where crops are mixed with natural vegetation, such as in Africa, monitoring crop status directly is a challenge. In this case, NDVI decrease is measured after the harvest, providing an estimation of drought that affected both crops and natural vegetation.

### **Pioneering Products**

To date, pilot projects have been developed to provide insurance to farmers based on vegetation status products derived from satellite observations. This section gives a few examples of programs that have used satellite-derived payout triggers.

#### *Index Insurance for Rangeland and Pasture*

- United States Department of Agriculture (USDA) Risk Management Agency (RMA) issues insurance programs for pasture, rangeland, and forage using two indices to determine pasture conditions (rainfall index and NDVI) ([http://www.rma.usda.gov/policies/pasture\\_rangeforage/](http://www.rma.usda.gov/policies/pasture_rangeforage/)). The Vegetation Index Plan of Insurance is designed as a risk

management tool to insure against a decline in the vegetation index in a designated area of roughly 4.8-miles (8km) square grid.

#### *Index Insurance for Crops*

- The Agriculture Insurance Company (AIC) in India proposes a wheat insurance policy based on satellite images to capture crop vigor (biomass) and assess claim payouts to farmers (Financial Daily, Dec 05 2005). The Wheat Insurance Policy is a unique technology-based insurance product which provides risk management to wheat producers who are likely to be impacted by poor growth of the crop arising out of non-preventable natural factors (AIC, Wheat Insurance Policy)
- The Millennium Villages Project (Earth Institute Columbia University and UNDP) in partnership with Swiss Re has developed and implemented a drought index insurance program in a number of rural villages in 10 countries in Africa. To date, three drought insurance contracts, two of which are solely based on NDVI, have been implemented. Preliminary results point toward optimism in the ability for NDVI to reliably pick out most of the major drought years in many locations, particularly in regions with high seasonal NDVI variance such as the semi-arid Sahel region of Africa (Ward *et al.* 2008).
- In Ethiopia, crop insurance has recently been extended to more than six million people (IRIN NEWS, September 16, 2008<sup>1</sup>). This project, co-developed by WFP, the World Bank, and FAO, is working with the Ethiopian government to implement drought indices based on crop water requirement models, gauge-enhanced satellite rainfall and vegetation index at 1km<sup>2</sup> spatial resolution.

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<http://www.irinnews.org/Report.aspx?ReportId=75865>

## Opportunities and Challenges in using NDVI

### Opportunities

Many NDVI products are available through the internet, produced by several national space agencies. Daily observations of global vegetation dynamics have been made since 1981. NDVI datasets derived from several different satellites at spatial resolutions varying from 1km to 8km (grid size) are available.

Data from the National Oceanic and Atmospheric Administration (NOAA) Advanced Very High Resolution Radiometer (AVHRR) meteorological satellites has been used to create twenty-six year datasets by a number of different organizations, including NASA Global Monitoring and Modeling Systems (Tucker *et al.*, 2005), NOAA NESDIS (Jiang *et al.*, 2008), and NOAA EROS (Eidenshink and Faundeen, 1994). In addition, new investment in the global AVHRR data record has enabled the reprocessing using improved techniques that have improved the resolution of the data to 4km globally since 1981 (Pedelty *et al.*, 2007). This long-time period allows the identification of local and sub-regional drought and enables identification of the worst drought years in order to establish insurance policies.

Recently, sensors with higher spatial resolution than 1km are becoming available. Currently, sensors with spatial resolution ranging from 100m to below 10m are available allowing the identification of very precise areas with pasture or crop problems.

NASA's MODIS (the MODerate Resolution Imaging Spectroradiometer) is a source of extremely high quality NDVI data and now has an 8 year long data record. Recent investments by the US Department of Agriculture will soon result in a global NDVI product with 9 hour

latency and 500 m resolution which will enable rapid analysis of crop conditions (Huete *et al.*, 2002).

### Challenges

There are a number of challenges for using NDVI data in a crop insurance scheme that have been taken into account to establish pilot contracts. These include:

- Low spatial resolution of 4- 8km for long term data records is a problem for monitoring crops in regions where agricultural production occurs at spatial scales finer than 1km. This low resolution is however superior to that of many ground-based rain gauge networks in the developing world.
- NDVI values vary from one sensor to another. NDVI values can differ over the same area depending on the sensor used (Brown *et al.*, 2006).
- Change in quality of a dataset over time because of calibration and data correction, particularly when comparing real time data to historical datasets that may have a different processing scheme (Brown, 2008).
- For crops, NDVI measures greenness not seed productivity. NDVI is used as a surrogate for monitoring stress conditions due to drought.
- Cloud contamination poses a very real obstacle. 'False alarms' due to cloud contamination could trigger insurance payouts in above normal years.

### Possible Improvements and Research Priorities

- Low spatial resolution for monitoring crops at finer spatial scale: **Solutions:** i) Monitor the crop and vegetation within the grid and investigate the relationship between phenology of agriculture and native vegetation. ii) Investigate the use of higher spatial resolution data.
- NDVI consistency between sensors and change in quality of a dataset over time: **Solutions:** i) Use statistical approaches that incorporate multiple sensors and normalize the actual measured NDVI

according to standard deviations and variance ii) Use new methods to optimize retrieval of vegetation status independently of the sensors (use a new optimized index: FAPAR, Gobron *et al.*, 2000) iii) Develop new metrics that enable a quantification of the relationship with crop production for each sensor (see Funk and Budde, 2008 and Brown and De Beurs, 2008)

- Measurement of greenness and crop production problems. **Solution:** In each location where the insurance program will be implemented, collect production and yield statistics for the past and estimate relationship between vegetation and crop production.
- Role of other factors (*e.g.* disease, nutrient depletion, pests, wind, and hail) in yield outcomes: **Solution:** Use ground measurement to understand non-productivity related factors in widespread production declines, and to use this knowledge to establish a clause in insurance contracts specifying these exceptions.
- Cloud contamination: **Solution:** Improve algorithms to identify and mask clouds.

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