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Remote sensing technologies for crop insurance

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Abstract
Crops are at greater risk in the changing climate in present era. Crop insurance plays crucial role in livelihood resilient agriculture as they provide better support to farmers under adverse conditions. Farmers in the developing world will be able to insure against harvest failure if robust insurance packages, based on a geophysical index rather than individual loss, become widely available. Remote Sensing Technology (RST) is the emerging technology with potential to offer plenty of supplementary, complimentary and value-added functions for crop insurance. Application areas of RST includes acreage estimation, crop health reports, yield modeling, reduction of sample size of CCEs, soil moisture determination (RADAR), rainfall estimates etc. However, RST also faces certain challenges due to heterogeneous croplands, data quality, poor identification of small crop areas, cloud coverage etc. Thus, RST for crop insurance requires further research along with greater cooperation between the insurance industry and the remote sensing community to help farmers minimizing their crop failure risks.

Keywords: Biomass index, crop cutting experiments, crop insurance, NDVI, remote sensing index

1. Introduction
Uncertainty of crop yield is one of the fundamental risks, which every farmer faces all over the country. Climate change with its potential to alter seasons, rainfall variability and temperature regimes poses a growing threat to the development agenda. Small-scale farmers in developing countries are among those most vulnerable to changing patterns of rainfall and temperature (Brown *et al*., 2011) [1]. These risks are particularly high, in developing countries particularly in the 'tropics' as in most of these countries, farmers are poor, with extremely limited means and resources. Therefore, there is an urgent need of improved crop insurance to safeguard farmer's interest, whether of developed or developing nation.

1.1 Types of crop insurances are
1. Area based index
2. Yield based index
3. Weather Based Index
4. Production index
5. Remotes Sensing based index

2. Remotes Sensing based index
The scope for application of remote sensing by the insurance industry is based on indices which can be constructed that correlate well with what is in which are not only important for verifying claims and also strengthen the position of insurers vis-à-vis re-insurance market.
Major products in which this technology is being used in these countries are Hail Insurance and Multi-Peril Crop Insurance (USA, Canada, Australia etc.). These products are based on specified perils, and hence claims become payable only if the losses are on account of these specified perils.

2.1 Remote Sensing provides the insurers with tools like
1. Hazard mapping,
2. Crop health reports
3. Acreage-sown confirmation, yield modeling etc.

2.2 Merits of Remote Sensing in crop insurance
a. Greater credibility to insurer's efforts towards securing re-insurance.
b. Unbiased, objective and independent data to crosscheck and supplement other field information inputs.

e. Making insurance affordable to low income households.
f. Reducing fraud, moral hazard and adverse selection.
g. Eliminating the burden of costly verification of claims on-the ground.
h. Enabling faster and cheaper payouts to the insured.
i. Provide insurance to farmers in remote areas.
j. Remove area discrepancy in coverage

2.3 Designing and Pricing an Index-based Contract
An elementary contract pays an indemnity f (τ) conditional on realization of the index τ according to the following schedule:

$$f(\tau) = \begin{cases} x \; if \; [\tau \leq xi^*] \dots\dots\dots\dots \text{i} \\ x \dfrac{i^* - \tau}{(1-\lambda)i^*} \; if \; [\, \lambda i^* \leq \tau < i^* \dots\dots \text{ii} \\ 0 \; if \; [\tau > i^*] \dots\dots\dots\dots\dots \text{iii} \end{cases}$$

This means that the contract pays whenever the index τ falls below a pre-defined trigger $i*$ the three cases above illustrate that: for case (*i*) *a maximum indemnity* INR x is paid since the index falls below critical value λ$i*$. For case (ii), an indemnity proportional to the difference between the index and trigger is paid for λ$i*$ ≤τ < $i*$, *and* for case (iii) no indemnity is paid, if the realized index τ is above the trigger i*. The parameter 0 ≤ λ < 1is interpreted as the probability of ruin and signifies a catastrophe if its value is closer to 1 and non-catastrophe otherwise. For extreme catastrophe, λ = 1and the contract pays the maximum indemnity, if the index falls below the trigger level $i*$, but pays nothing otherwise.

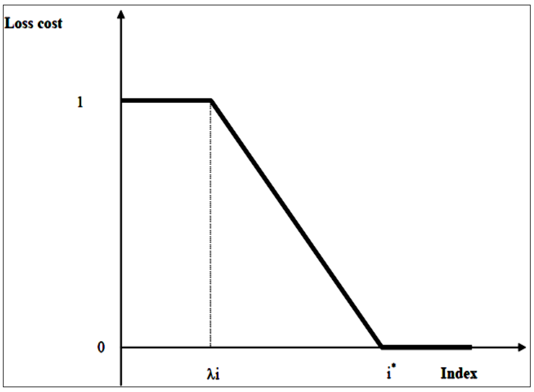

Fig 1: NDVI based Indemnity Schedule for a Standard unit contract

3. Use of Remote Sensing technologies to rationalize CCEs
With availability of number of satellites with high resolution images orbiting the Earth, Satellite imagery can help in demarcating the cropped areas into clusters on basis of crop health. This feature can be successfully used to target the CCEs within the Insurance Unit (IU) - 'smart sampling' of CCEs (Leeuw *et al*., 2014) [2]. Minimize the total CCEs needed by about 30-40%. Estimates at Tehsil level can be attempted through the crop surveys earlier planned for district level estimators (Singh 2012).

While an IU with heterogeneous crop health may need standard sample of CCEs, (*eg*. 4 CCEs per Village / Village Panchayat), the more homogenous IU may need a lesser sample size, (eg. 2 CCEs). For using satellite data for smart sampling, there is need to generate specific crop map. Vegetation Indices need to be computed for the cropped area. On basis of Vegetation Index, the crop area can be categorized into poor, medium, good and very good crop health strata. Within each stratum, CCE points should be selected randomly. This can be done in consultation with MNCFC and IASRI.

3.1 Initial situation: Dominance of NDVI
Most prominent vegetation indices used is the NDVI (Normalised Difference Vegetation Index).

The advantages of this index
1. Data are recorded daily by different sensors, and
2. Time-series of up to 30 years are available.

Disadvantages include
1. Inaccuracies due to background reflectance and the three-dimensional structure of the canopy.
2. NDVI values depend on sensors used.
3. Affected by factors such as soil moisture.

Thus, alternative indices are currently being developed such as FAPAR (Fraction of Absorbed Photosynthetically Active Radiation), VHI (Vegetation Health Index), Biomass index and LAI (Leaf Area Index).

3.2 Biomass index
Biomass (Crop Health) Index- Based on the NDVI and yield correlation, the triggers have been defined at a level between 95 to 85 percent of past 10 year's average. It is based on satellite image derived NDVI. It is used to model the yield estimates, and a definite possibility of replacing manual yield estimation.

4. Challenges for applying Remote Sensing technology for crop insurance
1. Insured area is relatively small (*eg*. 1 ha approx. 100 ha), so, relatively high spatial resolution is required.
2. Vegetation period required is 4 to 9 months. Medium temporal resolution is required. High temporal resolution required if RS is to be used after a specific loss event
3. Biomass is not always equal to yield.
4. Ground truth data essential for calibration and validation which will lead to reliable yield data.
5. Noisy data can lead to inaccuracies.
6. The finer resolution satellite data is expensive.
7. A lot of crops with less biomass are difficult to figure out through satellite imagery.
8. Lack of continuous data delivery.

5. Summary
Satellite technology has considerable potential to develop and enhance crop insurance and the disaster response of state authorities after major losses. With the development of reliable regional yield estimates by remote sensing technology, corresponding area yield insurance products will come. Advances in the field of radar data may supplement optical data thereby easing these cloud constraints. Lack of mutual understanding and therefore need of greater cooperation between the insurance industry and the remote sensing community is required.

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