Remote sensing-based transformative crop insurance for rice

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A robust crop insurance system is critical to limit the impact of multivariable risks and stimulate innovation and investment in the agricultural sectors. A genuine agricultural insurance claim is lacking in India due to unavailability of accurate data. Manual data collection of cropped area, prevented sowing, failed sowing, and flood- and drought-affected areas is laborious, time-consuming, cost-intensive and often erroneous. The existing insurance procedure is not transparent, accurate and fast due to the aforesaid issues. We can overcome these problems using satellite-based remote sensing. An alternative measure of paddy crop performance through crop health factor index derived from synthetic aperture radar remote sensing data can be utilized in place of yield data in the existing area–yield insurance scheme. Tamil Nadu and West Bengal have successfully implemented this technology, which can be applied across India to make crop insurance transparent, accurate and rapid.

Agricultural insurance covers natural disasters such as fires, floods, droughts, cyclones, crop diseases, insect invasions, failed sowing due to lack of rainfall, etc. which cause economic loss to the farmers. In response to the growing challenges posed by extreme weather events, having access to credible information is critical. To have legal grounds for potential claims, farmers must insure their crops before the start of the season or sowing. Agricultural insurance benefits marginal and small farmers by protecting them from the potentially disastrous repercussions of crop failure and also increases their economic resilience. Crop insurance helps farmers to repay their loans if a crop fails, provides economic stability in the event of agricultural losses and supports replanting in the event of failed sowing. However, only crops and livestock are covered under agricultural insurance, which does not cover damage to farm infrastructure.

India has had a long history of establishing various crop insurance schemes since 1972 (ref. 1). The countrywide schemes include Comprehensive Crop Insurance Scheme introduced in 1985, the National Agricultural Insurance Scheme (NAIS) in 2000, Weather Based Crop Insurance Scheme in 2007, Modified NAIS (MNAIS) in 2010 and Pradhan Mantri Fasal Bima Yojana (PMFBY) in 2016. In the past, the most prominent area–yield crop insurance schemes, viz. NAIS and MNAIS, had serious shortcomings, such as a lack of trustworthy crop yield data and insufficient coverage[2]. Several factors limited weather-based crop insurance, including complex relationships between weather and crop yield, insufficient representation of geographical variability in meteorological conditions, and underrepresentation of weather-related problems (pests and diseases)[3]. According to Smith and Watts[4], index-based insurance schemes in poor countries face significant challenges due to the lack of trustworthy historical data, making the long-term scalability and sustainability of agricultural insurance a major concern. As a result of these deficiencies, even in years with favourable weather conditions, the compensation payments have exceeded the premium[5].

PMFBY uses an area strategy, i.e. unit area of insurance (IU), which is typically a collection of villages known as a Gram Panchayat. Crop-yield estimates from IU for the current and previous years are used to calculate yield loss and compensation payments. For the current year, a percentage of the average yield of the previous five best out of seven years of an IU called threshold yield (TY) is guaranteed. Actuarial premium rates are set for each crop at the district level, depending on the previous risk profiles of IU in the area. To determine the payout, the current year's yield shortfall from TY of the crop in IU is applied to the sum insured. As a result, the most significant challenge in India's area–yield crop insurance remains the generation of accurate crop yield data for current and previous years in the insurance units[6]. Crop yields are calculated using crop cutting experiments (CCEs), which involve manual assessment of yield in randomly selected fields for each crop in each IU. The minimum number of measurements and their propensity to bias have become important obstacles in generating reliable yield estimates. As a result, the anticipated yield of an IU often differs from the actual yield, causing data discrepancies and claims settlement delays.

Remote sensing data assist governments and agricultural intermediaries in managing domestic rice production and distribution, both during normal and natural disaster-affected years. Such information is critical for insurers to reduce risk and develop new insurance programmes that are affordable to low-income, smallholder farmers. The presence of clouds during the monsoon season is the main obstacle for obtaining ground information through optical remote sensing. Whereas microwave remote sensing has the ability to penetrate clouds and give correct information about the objects on the earth surface. In the past, the processing of microwave remote sensing data was not easy compared to optical remote sensing. The recent development of advanced tools and technology like Google Earth Engine, MapScape rice, SNAP, etc. has made the analysis of microwave data easier and faster compared to optical remote sensing. The dielectric constant and surface roughness are two major factors that influence the backscattering of microwave remote sensing. The unique spectral signature of transplanted rice fields in microwave remote sensing helps identify the start of the season, area under rice, growth stages, biophysical parameters like LAI, yield, etc.

Using regularly acquired synthetic aperture radar (SAR) satellite data, rice-planted area and phenology are monitored throughout the growing season. When combined with a rice growth model, remotely sensed data can forecast rice yield starting in the middle of the crop season, estimate yield at harvest time and provide continuous updates on the rice production status. The Sentinel-1 SAR satellite data-based crop insurance will provide several benefits. (i) Accurate field area measurement: With the availability of high-resolution satellite imagery (20 m × 20 m), we can now estimate the area under rice crop and predict the yield for a larger geographical area with

>90% accuracy[7]. (ii) Monitoring of rice crop health status: Satellite technology measures the normalized difference vegetation index (NDVI) to determine vegetation density and health status of rice. (iii) Accurate prediction of rice productivity: Rice yield is estimated with >90% accuracy using biophysical observations like LAI derived from SAR satellite imagery and crop simulation models (Oryza). (iv) Keeping the crop insurance process transparent and ensuring fast payouts that enable insurance firms to solve a variety of issues. (v) Provides access to accurate, up-to-date data at any time, both on-line and offline. (vi) Farmers and crop insurance providers can swiftly acquire and verify all relevant information. (vii) Saves time and resources, and improves work quality.

The Government of Tamil Nadu for example, has made substantial investment to move to a state-level monitoring system that is based on the RIICE (remote sensing-based information and insurance for crops in emerging economies) technology. Insurers can use this technology for loss/damage assessment after natural disasters within the Governmental crop insurance scheme. Tamil Nadu is the first state in India to settle insurance claims through remote sensing under PMFBY. The 2015 flood in Tamil Nadu caused severe damage to rice. With the help of SAR remote sensing the affected rice areas were mapped and 50 tonnes of short-duration paddy variety seeds were distributed in areas where the rice crop was damaged severely. Distribution of short-duration variety seeds in the affected areas ensured crop cultivation in failed sowing (crop does not germinate due to lack of rainfall or floods) and prevented sowing (no crop sowing due to delayed rainfall) areas. In 2017, the Agricultural Insurance Company of India paid the first ever claim on prevented sowing compensation to approximately 22,500 rice farmers in the Trichy district of Tamil Nadu after severe monsoon failure.

The satellite-derived crop health index could be used instead of yield data in insurance schemes. This new approach was adopted in West Bengal, in 2020, covering 3.5 million acres of paddy crop across 3200 insurance units. Sentinel satellite data, gridded weather data and mobile app-based field data were used to generate a paddy crop map and crop health indicators, including NDVI, land surface water index, backscatter, and fraction of absorbed photosynthetically active radiation. Crop health factor (CHF), a composite index of crop performance ranging from 0 to 1, was developed using metrics obtained from these indices and the entropy approach. Insurance firms use CHF instead of yield data in the existing area–yield insurance schemes, as CHF and yield deviations between years reveal a strong link[8].

The accuracy of SAR remote sensing depends on many factors. (i) Local agronomic knowledge (time of sowing, season, method of establishment, cultural practices) of the expert who analyses the data plays a significant role in deriving an appropriate conclusion. (ii) Processing of SAR imagery requires high-end computers and software which are expensive and not available with most of the State Departments. (iii) The accuracy is more in areas having uniform cropping system and is relatively lower in the highly diversified cropping systems. (iv) A GPS-based CCE is required to validate the model output which is again laborious, time-consuming and cost-intensive. A few factors may hinder the large-scale application of remote sensing technology which include: (i) the high cost of remote sensing data (the high spatial and temporal resolution SAR imagery is not available free of cost. (ii) At present, India does not have an independent, high spatial and temporal resolution SAR satellite. We are utilizing the European Space Agency data (Sentinel-1), which is available free of cost. (iii) Lack of capacity-building programmes and trained manpower resources.

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