The Challenges of Agricultural Index Insurance: Best Practices for the Earth Observation Sector

White Paper

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INTRODUCTION

Index or parametric insurance has been offered internationally to manage risks in agriculture for over 20 years. It is a substitute to traditional indemnity insurance where payouts are explicitly based on loss estimations per each insured unit for a specific client. Index insurance relies on an index that is a proxy for a loss caused by an insured peril, allowing to provide farmers with efficient risk management solutions for perils which are either expensive (e.g. insurance on small field sizes) or difficult to insure (e.g. drought, tropical cyclones, flood, excessive rainfall) due to its systemic nature.

Index insurance products are intrinsically imperfect because they rely on proxies of a loss and not on actual observed crop damage.[1] The residual uncertainty between the index and the actual crop damage is called a "basis risk". Basis risk can originate as a result of data quality or originate from the index calculation methodology and result in an index inability to respond to losses and to initiate insurance payouts and vice versa result in payouts without an actual occurred loss.

The insurance companies and organizations that design index insurance products for agriculture seek for the options to get better quality data for index design. There have been increasing efforts during the last years to make more and better use of remote sensing information from satellites to enhance or replace existing insurance products (e.g. precipitation based index products) and/or to enhance data quality and fill in the existing gaps in the data sets. While earth observation (EO) provides additional historical and near real-time data to improve index insurance products from the technical perspective, application of satellite technologies and data remains still limited within the agricultural insurance industry. The success of the uptake of Earth Observation (EO) data for index insurance depends on multiple factors and challenges (Figure 1). This paper wants to raise awareness on possibilities and capabilities for both sectors, the agro-insurance sector as well as the earth observation sector.

This paper is dedicated exclusively to index insurance as a risk management instrument in agriculture with the forward thinking of applying satellite data and technologies to enhance the existing insurance solutions, covering the traditional indemnity and index insurance products.

- **Data availability** (quality index design requires 25 to 30 years of data)
- **Correlation** between measured parameters (soil moisture, rainfall, temperature) and crop condition
- **Integration** of satellite data solutions into the existing IT systems at insurance companies
- **Data quality and continuity** of data supply (cloud cover impact on optical data acquisition
- **Data integrity** (correlation between remote sensed parameters and data collected from ground-based sensors)
- Complexity of satellite **data interpretation**
- Accurate **estimation of crop yields**
- **Lack of technical capacity** and understanding of remote sensing data and technologies within insurance companies
- **Farmers' awareness and trust** to index insurance solutions based on satellite data
- Accurate **crop type identification**
- The **cost of satellite data** to insurance companies, especially for high-resolution data
- **Customer communication** and dispute resolution when a farmer experiences a loss but pay out is not triggered by index structure (basis risk)

Figure 1: The key challenges of index insurance from the satellite earth observation technologies perspective.

WHAT IS INDEX INSURANCE?

Index/Parametric insurance is often defined as a type of insurance that covers the probability of a predefined event happening instead of indemnifying the actual loss incurred.[2] This definition represents a certain issue when index insurance contract does not cover an actual loss or pays when the insured farmer did not experience a loss, also known as the basis risk.

Currently the index insurance paradigm is being reconsidered. It is no longer perceived as a "silver bullet" capable of substituting the indemnity insurance. Munich Re specifies that "parametric products provide a simple and transparent coverage concept for insurers, businesses and the public sector alike. They complement traditional insurance coverage for policyholders aiming to reduce their risk exposure and can cover risks that have traditionally been uninsurable".[3]

According to the World Bank,[4] index-based crop and livestock insurance was the most dynamic type of agricultural insurance during the last 10 years. While in 2009 agricultural index insurance provided 3% of the global agricultural insurance premium, its premium share increased to 12% in 2019. This growth is attributed to numerous index insurance pilot initiatives in developing countries in Africa, Asia and Latin America.

The major types of index insurance products are presented at the figure below. Weather index and parametric insurance products are intentionally defined separately because of different product structures and premium rate calculation methods applied. Parametric products are designed to respond on a specific event occurrence (e.g. tropical cyclone of category 5 hitting a defined area or a specified forestry area to be lost due to fire) before the payout is triggered. Weather index products are usually developed using historical weather data, sometimes including crop models to capture crop loss or severe damage at a certain vegetation phase linked to multi-year average phase dates.

It can be argued if picture-based insurance can be defined as an index insurance. This new type of insurance is suggested in this paper to be treated as index insurance because new technologies (satellite-derived index data used together with photos supplied by the insured farmer) can support such products with underwriting and loss assessment done remotely.

Index insurance solutions for the livestock sector are less numerous comparing to crop production. Livestock index structures were developed to respond to livestock loss due to such severe events as snow storms, long periods with low temperatures or floods. Satellite-data based products have been developed for pastures and forage crops. These products are usually based on vegetation indexes such as NDVI or EVI or soil moisture (drought) measured by satellite sensors.

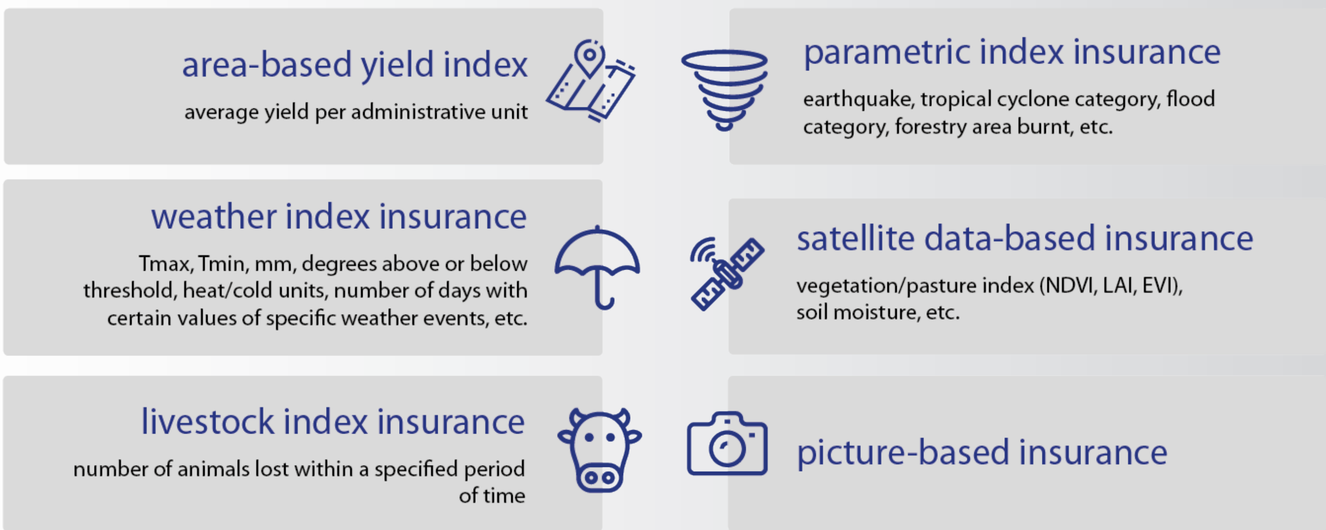

Figure 2: Major types of index insurance products for agriculture

KEY CHALLENGES OF INDEX INSURANCE

CUSTOMER NEEDS

Agricultural insurance is an effective risk management instrument but the actual uptake of insurance products is hampered by availability (distribution models), sufficient information about the existing insurance solutions, timeliness of loss payment, complexity of claim handling process and fairness of the payouts.

Farmers expect loss payment within 2-4 weeks after a loss event or within 30-45 days after harvest completion. For total loss cases, the payment process can be very quick when it is evident that the assets are lost but with crop damage, some time may be required to understand the extent of damage. Traditional indemnity insurance usually complies with this requirement but sometimes this takes some time and involved some administrative work also on the farmers' side. Sometimes farmers also have reservations in respect of objectivity of loss assessment.

Index insurance products provide a good alternative to traditional insurance as the payment can be performed by the insurer without loss assessment inspections once the insured event is triggered. Currently remote sensing data providers can supply data for claim processing quickly (1 to 5 days) with short time required for data acquisition, processing, reporting and delivery to the insurer. This is sufficient for insurers with claims handling cycle to fit within 2-3 weeks which must be in line with farmers' expectations.

BASIS RISK

The key challenges for weather index, parametric and satellite data index products are the accuracy of data and payout correlation with the farmers' actual crop yield loss or animal loss. Correlation between loss compensation and actual loss is the critical factor for any index insurance product. The farmers are usually tolerant to certain difference in loss estimation (eg. 10%) and may object loss estimates if the difference is larger.

Several types of basis risk are critical for the success of index insurance programs that are summarised in Figure 3.

Insurance practitioners often rely on third-party data to support an index design. A good working relationship with the 3rd party to understand impacts (data and operational) is important and can influence the degree of "basis risk" within the system.

The satellite Earth Observation (EO) technologies may help reducing basis risks for agricultural index insurance products. This requires additional instruments or new sensors on satellites as well as enhanced models and innovative index design methodologies to mitigate the basis risk impact. The ultimate objective is to improve the correlation between remote sensed parameters and the crop condition or yield estimation at each field insured.

SATELLITE DATA-BASED INDEX INSURANCE

Satellite data-based index insurance products have been introduced as an alternative solution to weather index insurance. Vegetation indexes, calculated using earth observation data, help to assess crop condition at a specific field with the definition of problem spots at high resolution. Satellite imagery provides a good view of the crop development from emergence to harvest time. A big advantage of vegetation indexes when comparing to weather indexes is that they capture the impact of multiple factors that are important for crop development (e.g. soil water holding capacity, crop response to meteorological conditions), as well as the problems originating from crop management practices.

Satellite vegetation data proved to be useful for insurance of pastures and forage crops when it is necessary to assess the volume of the green mass produced at the field. Vegetation index insurance products have been tested in different countries with the working programs in the USA and Canada. At the same time, vegetation index insurance products for field (non-pasture) crops are still in a development stage due to the difficulty to establish an accurate correlation between vegetation indexes and crop yields.

spatial variance

variation in weather parameters in areas around ground-based weather stations whose data are used for index design.* Actual weather parameters can differ significantly from those recorded at weather stations. Data accuracy may drop significantly with growing distance to the measuring station due to various local factors such as water surfaces, forests or terrain profile.

* Weather derivatives, spatial aggregation, and systemic risk: Implications for reinsurance hedging by J.D. Woodard, P. Garcia, J. Ag. Res. Econ., 33 (2008), pp. 34-51

sensor instrument

data accuracy depends on the type of sensors or equipment installed at the ground-based weather station. For example, manual and automatic rain gauges, tipping-bucket and weighing rain gauges have different technical features and accuracy of measurements which can vary significantly.

remote sensing technology

Uncertainty is one of the most common challenges among the diverse areas of remote sensing and impacts the basis risk of index insurance inputs such as meteorological data or Earth Observation (EO) proxies for yield loss. Satellite weather data delivers certain basis risk due to types of sensors, calibration capabilities, data acquisition schedules, data processing approaches and methodologies. EO proxies for yield loss derived from either optical satellites (e.g. Vegetation Indices) or radar satellites (e.g. soil moisture) are also sensible to data uncertainties due to various factors such as sensor calibration, algorithm uncertainties, mismatch in spatial footprint.

temporal challenges

the timing of crop vegetation (phenological) phases for a given crop can variate in different years and may not match the coverage period provided by a weather index insurance contract. This can occur due to soil moisture level and specific weather conditions at the sowing window or slow/faster plants development due to temperature and rainfall regime before the agreed coverage period.

procedural (data collection)

this type of basis risk is critical for all types of index insurance products. At the ground stations weather data can be collected using different timing protocols (every 3 hours, 2 times during 24 hours, etc.). This difference may significantly affect the quality of rainfall data during warm period of year. Capturing of maximum and minimum temperatures without recording the duration of extreme events may result in lower efficiency of index covers. Site maintenance and location of private automatic weather stations may significantly affect data quality resulting in higher basis risk for both farmers and insurers. The yield estimation procedure proved to be critical for area-yield index insurance. The selection of the sufficient number of test plots for assessing crop yield must be done according to the established methodology to get representative data at the insured and non-insured fields.

product design

originates from poor relationship between the insured parameters (weather) and crop condition and yields. Many index insurance products provide coverage against one or several perils but often there are additional factors affecting the actual crop yield which result in no payouts while the farmer has lost his/her crop. Several index elements work in concert to impact yield such as: soil substrate, precipitation at various depths, solar radiation, temperature, wind, etc., as well as in-field management by the producer. The interaction of these elements is as important as their recording. In other words, product design should include an accurate measure of these individual elements (with an associated basic risk potential) and some notion of their working relationship toward a yield outcome. This is a challenging aspect of index based agricultural insurance design.

missing data substitution*

can increase basis risk – this occurs when an index element is not generated - for example at a weather station (e.g. precipitation, temperature) or satellite platform (interruption due to cloud cover or wild fire haze). The method of missing data substitution should be known by insurance practitioners and the source recorded for each missing value should be substituted in order to track the impact on any loss calculation. In addition, different formula may be available and currently in use for functions other than crop insurance design (e.g. by the operators of the weather station network for climate change monitoring, etc.).

*Communication with Rick McConnell, DYMAC Risk Management Solutions Ltd. (Canada)

Figure 3: Types of basis risk that are critical for the success of index insurance programs.

Optical satellite data is available practically for all agricultural regions in the world since the early 80's at low resolution while the public access to high resolution data with a frequent revisit time is opened since the operationalisation of the Sentinel 2 satellite in 2016. These data can be used by insurers for premium rate setting purposes which is especially useful when the insurers covered only some percentage of the crop in the previous seasons and historical loss adjustment records may not be representative for a specific region. Besides optical satellite imagery, radar data is a good source of information on crop growth. Its main advantage is that it can penetrate to clouds and thus also provides crop information in cloudy periods. Publicly available high resolution radar (SAR) data are available for the last 7 years since the launch of Sentinel 1.

The key challenge for insurers is the interpretation of vegetation data. While vegetation indices provide a good measure of the greenness of the canopy (e.g. NDVI), or photosynthetic activity (e.g. fAPAR), they do not directly correlate with crop yield. The main reason for this is that the underlying processes impacting yield are not directly observed and these effects are not always visible in the canopy. For example, frost or heat stress events at flowering stage (e.g. during the maize fertilization stage) or lack of moisture during crop maturity stage. Extensive in-situ measurements are required to adjust the index methodology and to develop accurate correlation calculations for the vegetation indexes to provide accurate yield estimation.

The other requirement is the revisit schedule for data collection. Currently most satellites deliver optical or radar data every 3-7 days which is sufficient for crop monitoring but not practical for loss estimation. Optical vegetation data may not be available for a continuous period of time if the area of interest is under cloud cover. Recent developments to merge both optical and radar data streams support however an ensured continuous monitoring of crops.

Vegetation imagery data is challenging to interpret for insurers. The insurance companies usually do not have scientists or vegetation data experts to provide accurate advice on the crop condition and the extent of loss. Also, the insurers must make quick decision on crop condition (underwriting) or damage/loss, especially when crop is being affected by high risk events. The insurers need technology solutions to provide analytical reports based on satellite data with accurate advice on the crop condition or loss.

The key requirements to the satellite vegetation data to be used for index insurance products:

- Seamless data flow with as short as possible revisit schedule;
- Automatic data interpretation and provision of data for claim calculation or crop assessment;
- Calibration of satellite data to increase accuracy of crop yield and green mass volume estimates;
- Accurate crop type identification, using both historical and real-time satellite data;
- Affordable pricing for satellite data and sustainable delivery models to be in line with the insurers processes and needs.
- Flexibility to adjust to insurers specific requirements

WHERE CAN EO CONTRIBUTE?

The EO industry can support agricultural insurers with huge volume of historical and near-real time data for any type of insurance products. The cost of data has reduced significantly currently with different resolution available to meet the insurers' needs. Satellite industry can supply data for portfolio monitoring, underwriting, loss adjustment and claims handling.

The key challenges of EO industry are the affordable and easy-to-integrate technology solutions, generating the required analytical reporting, providing sufficient accuracy of crop loss and/or crop yield estimation and developing pricing models. Often insurance companies lack EO experts with sufficient agricultural background, which slows down the introduction of technology-driven solutions for agricultural insurance.

Insurers require the processed data to enhance their underwriting and loss adjustment processes, better manage moral hazard, adverse selection and asymmetry of information. From the practical perspective, insurance experts need additional data and technology for quick and efficient management of underwriting decisions and loss adjustment assignments.

As it was discussed earlier in this document, integration of new technology solutions into the existing insurance IT systems may be challenging, especially from the cyber security perspective. Specific satellite remote sensing and weather data, required for agricultural insurance underwriting and loss adjustment, may not be relevant for the general insurance IT systems. It is suggested that the stand-alone platforms may be a cheaper and more practical solution to meet the needs of agricultural insurance providers. However, such solutions must include specific functionalities to allow agricultural underwriters and loss adjusters to download the necessary documents and reports into the general IT systems. This relates to analytical reports and specific information supporting underwriting decisions which must be saved to the individual underwriting files. Claims handling team must obtain and store the available information (yield estimation, crop damage maps, indexed imagery, index and trigger calculation spreadsheets, claim bordereaux, etc.) for future references in case the insured farmers would raise a dispute relating to the accuracy of loss assessment and claim calculation.

The new technology solutions for traditional, index and hybrid insurances may provide automatic or on-demand queries for high resolution data which may be required for specific fields or crop areas. This will be an important element of new platforms when applied to area yield index and hybrid insurance programs. This functionality will be of great use for traditional indemnity insurance to assist loss adjusters with crop loss and yield estimation at multiple fields[5].

The new platforms must be flexible to integrate various types of the existing and new types of data, including but not limited to optical and radar imagery, historical and near-real time weather data, soil moisture information, etc. The historical imagery and weather data can be utilized for premium rate setting, premium rate adjustment per individual farmers or fields and making underwriting decisions as for "insurability" of specific risks.

Several years ago, insurers struggled to get correct field location data but recently this is a manageable issue. The new platforms must be able to process any field identification data including GIS files (shp, kml, kmz, etc.) or GPS coordinates with automatic identification of the field boundaries.

It is advisable to include a portfolio mapping functionality to the new platforms to allow insurers easy monitoring of their portfolio practically in real time. Crop type identification feature can be of great assistance to the insurers to understand the total crop area and to compare it with the actual insured area (market share management and insurance penetration discovery). Some insurers offer several agricultural insurance products in addition to index insurance – portfolio mapping feature will provide insurers with very important information for portfolio and product management, reinsurance submissions, risk accumulation monitoring and business planning.

Risk pricing web-based solutions for index insurance are already used by insurance companies and calculation agents. Often index product structuring (trigger identification and payout schedule design) and pricing are very straightforward, especially if single data sets are used (rainfall data, NDVI indices). This results in a significant basis risk for farmers, especially if coarse data resolution and large grid cells are used, affecting the general index product acceptance and the customers' level of trust. The future platforms can merge different data sets, including historical yield and weather data, as well as loss adjustment data available at the insurance company. Such additional data can be applied for stress-testing index products to identify any problems with product design or trigger response in specific regions.

The most important GEO-information requirements for index products include:

- High-temporal/special uninterrupted data series;
- Soil type mapping (premium rate adjustment);
- Soil moisture monitoring (embargoes, application deadline adjustments, actual soil moisture index products);
- Identification and verification of field location and boundaries (accuracy of insurance coverage);
- Crop type identification (market share, portfolio management, reinsurance submissions, marketing campaign adjustment, etc.);
- Crop vegetation monitoring, including early vegetation stress identification (portfolio management, policy cancellation, fraud and moral hazard management, large losses early warning for logistical arrangements and resource preparedness);
- Crop emergence and harvest dates forecasting;
- Crop yield monitoring and yield estimation (loss adjustment, claim calculation, fraud and moral hazard management);
- Crop damage or loss identification based on vegetation index and weather data (identification of risk events and impact severity assessment, identification of total loss cases, more accurate loss adjustment in-field inspections, claim processing, fraud and moral hazard management);
- Biomass monitoring (pasture and forage crops insurance solutions, production practice monitoring)

The desired functionality of new technology solutions for agricultural insurance may include automatic alerts about the forecasted risk events with client communication products to be developed by the insurance companies in the future. This can be achieved by merging weather, SAR and optical data sets with dashboards providing the important information to the insured farmers.

WHAT'S NEXT?

EO industries are rapidly developing, enhancing data interpretation algorithms and generating new opportunities for index insurance applications. It is expected to experience larger inflow of new data from recently launched and future planned missions by institutional satellite operators such as ESA and NASA. Private satellite operators also show high interest in enhancing temporal and spatial resolution of new incoming data, providing commercial access to very high-resolution (VHR) optical datasets that already offer insurers capabilities to address agricultural underwriting and loss adjustment needs. The existing sub-meter resolution data already allows nowadays to address the challenges of index insurance. With the application of VHR optical data it is possible to better distinguish the risk effects with a much higher precision. VHR can be applied to manage basis risk in index insurance. In case if the trigger was not met but the insured farmer claims a loss, the insurer can verify loss using VHR imagery and weather data.

EO data operators will continue researching for better correlation of new data with crop loss and yield estimation and enhancing identification of crop damage using VHR optical and SAR datasets. While the technologies have strongly developed in the recent years (mainly by using artificial intelligence), the lack of ground based reference data to train and validate EO products is one of the main bottlenecks in a further operationalization of these services. In this context, collaborations are needed between the Earth Observation sector (which have the technology) and the agro-insurance sector (which have a better access to field data).

Insurance industry, pushed by COVID-19 effects, will continue introducing EO technologies in business processes. Insurers will require more consistent and precise data interpretation to further deploy EO technologies. It will supplement their portfolio management and future product development. At a time, insurers lack internal EO specialists who will be able to operate available data and generate necessary reports on their own. EO industry is expected to better accommodate the existing capacity gap and address the insurers' needs with better data exchange and reporting capabilities, enhancing functionality to achieve better underwriting decisions and optimize timing for faster indemnity payouts.

Another instance of future EO application is considered for merging the traditional indemnity insurance products with innovative index solu-

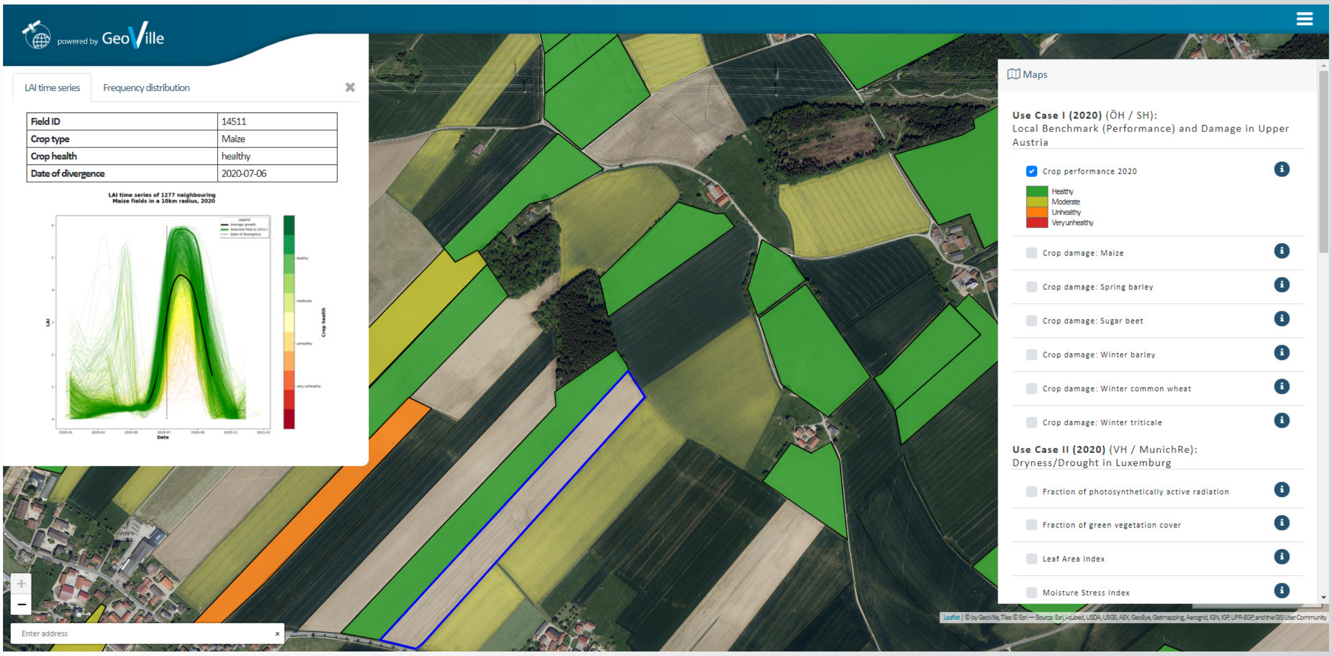

Figure 4: Demonstrator platform developed during the ESA EO Best Practice for AgroInsurance project.

tions, pushing the market towards the technology-driven hybrid insurance covers in agriculture. Innovative data-driven approaches in agricultural insurance will assist underwriting and claims to automate part of existing business processes, enhancing claims settlement and assuring faster indemnity payouts to the farmers. Solutions capable to provide multiple data layering, generating required reports with more precise estimations on crop yield or damage extent would attract more interest of agricultural insurers in the future.

Area-yield index insurance solutions will evolve searching for better data to get higher crop yields correlation to decrease the existing level of basis risk and rationalize yield estimation procedures. It is possible that the EO industry will develop new types of indexes to better identify the individual signatures of specific crop types from the emergence stage, including accurate identification of such look alike cereal crops as wheat, rye, barley, oats, etc.

New ways of crop yield estimation may be developed in near future. Application of artificial intellect and machine learning, big data processing algorithms together with the enhanced indices developed using the satellites may help us to estimate crop yields with higher accuracies. To date, the vegetation indices used currently for monitoring crop condition often do not correlate with the crop yields at the level acceptable for insurance solutions. Instead, more accurate crop yields can be expected by using multi-sensor approaches combining optical, radar, hyperspectral and fluorescence data together with soil and weather information. These data should be ideally connected with real time ground based yield data such as collected by sensors on-board of tractors during harvest, or yield losses quantified by loss adjusters on the field. In this way the highly accurate yield data collected on the parcel can be fed immediately into operational satellite based model, improving their quality.

Currently EO industry provides practical solutions for measuring soil moisture using passive microwaves in the top soil layer (5-10 centimeters). This technology is already used for soil-moisture index insurance to help farmers mitigate the negative impact of severe droughts. Although the moisture content in the top soil lets us assess the water available for the plants this concept does not take into account the water reserves in the deeper soil layers which agricultural crops can reach as their root system develops. Measuring deep soil (1-1,5 m) water content through the enhanced remote sensing will allow better index insurance designs for drought management. Combination of top and deep soil water measurements with other important parameters (evapotranspiration, relative humidity of air, etc.) can lead to development of sophisticated models which can be the basis for a new generation of agricultural insurance products in the future.

Hybrid insurance solutions will further emerge on the global insurance market involving more insurers and EO data providers to jointly search for solutions and address the needs of insured farmers. Parametric index insurance products possess the highest potential for future insurance applications for disaster risk management and post-recovery activities. They will continuously evolve towards addressing more risks and crops on farmers' specific demands. Parametric catastrophe index insurance covers will develop further with the assistance and support of national governments and international development organizations, with insurance cover applied at meso- and macro- levels (national scale).

Further attempts in combining various EO data layers will generate more opportunities for agricultural insurance, crop monitoring and yield estimation in the future. The comprehensive reporting will assist in efficient portfolio management, complementing the development of better insurance sales and more efficient client targeting strategies.

Notes

1 Index-based insurance challenges and socio-economic considerations. The ibli-kenya case by Federica Di Marcantonio. Geoprogress Journal, Vol. 3, Issue 1, 2016, Ed. Geoprogress. http://www.geoprogress.eu/wp-content/uploads/2017/07/GPJ-2015-Vol-3-I-5DiMarcantonio.pdf

2 https://corporatesolutions.swissre.com/insights/knowledge/what_is_parametric_insurance.html

3 https://www.munichre.com/en/solutions/for-industry-clients/parametric-solutions.html

4 Disaster risk finance for agriculture webinar, Module 6 – Risk Finance instruments 1 – Agricultural Insurance, October 12, 2021

5 Authors: multi-peril crop insurance requires yield assessment to be done at all insured fields, not only those affected by the perils. Comparison of crop yields within a certain geographic area may be required for managing fraud and moral hazard potential cases.

This study was developed in tight collaboration with the ESA Earth Observation Best Practice for AgroInsurance project, financed by ESA, and the project's stakeholders. Contributions by AgroInsurance International (Ian Shynkarenko, Roman Shynkarenko), GeoVille (Michaela Seewald) and VITO (Roel van Hoolst, Laurent Tits); revised by Nikolaus Neugebauer (Österreichische Hagelversicherung) and Max Strobl (Munich Re).

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Front Page:
Satellite imagery showing field damage caused by storm. Source: SkySat, Capella.

Backside:
Interrogated fields in Saudi Arabia. Source: Global Landcover Dynamics 2016-2018, GeoVille.