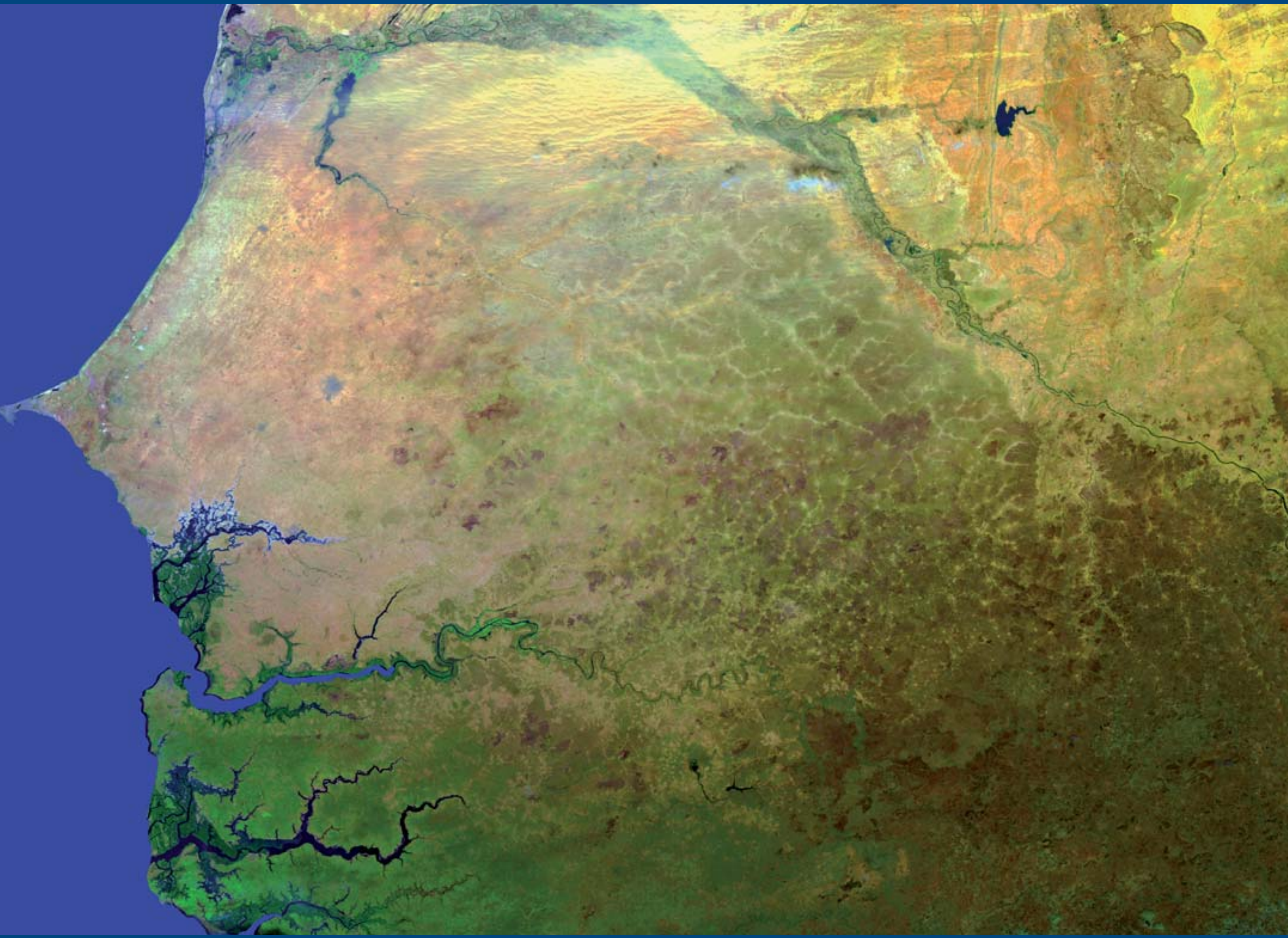

Remote sensing for index insurance

Findings and lessons so far

WFP World Food Programme wfp.org

IFAD Investing in rural people

afd Agence Française de Développement

This publication was developed for the Weather Risk Management Facility of the International Fund for Agricultural Development and the World Food Programme, by Andrea Stoppa, Emily Coleman, Francesco Rispoli, and William Dick. Sven Gilliams and Isabelle Piccard of the Flemish Institute for Technological Research (VITO) have provided significant contributions and support throughout the implementation of project activities. The publication also benefited from the editing support of Chris Jarzombek and Amal Magzoub. This project was made possible with funding from Agence Française de Développement.

ISBN 978-92-9072-561-9

Rome, March 2015

Front cover ©ESA-BELSPO 2015, produced by VITO
A PROBA-V satellite image of West Africa capturing Senegal, as well as The Gambia, Guinea and Guinea-Bissau.

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Investing in rural people

AGENCE FRANÇAISE DE DÉVELOPPEMENT

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1. Improving agricultural risk management in sub-Saharan Africa: remote sensing for index insurance

IFAD-WFP Weather Risk Management Facility

The Weather Risk Management Facility (WRMF) was established by the International Fund for Agricultural Development (IFAD) and the World Food Programme (WFP) in 2008. It supports initiatives aimed at reducing smallholders' vulnerability to weather and other agricultural production risks, in order to encourage and protect investments in smallholder agricultural production and contribute to food security. The WRMF does so through research, technical assistance and capacity-building, and implementation of innovative risk management solutions, such as agricultural index insurance. These initiatives have the potential to be mainstreamed within WFP's and IFAD's interventions as part of a holistic approach, and can also be used as wider public goods. WRMF comprises staff from IFAD's Inclusive Rural Financial Services team and WFP's Climate Resilience and Disaster Risk Reduction team, as well as international experts with a wide experience in index insurance assessment, development, design and roll-out.

Since its creation in 2008, WRMF has gained experience in multiple areas of index insurance. The partnership successfully designed, tested, and implemented index insurance pilots in China and Ethiopia, which have become the basis for other index insurance schemes. Based on these experiences and global research, WRMF has distilled key lessons for reaching scale and sustainability in index insurance, and defined the roles that public and private partners should play in its provision. Moreover, WRMF provides technical advice and supports capacity-building of projects, partners and staff.

Lack of good yield and weather data has been a key constraint in developing index insurance. Since 2012, WRMF has been implementing a project that seeks solutions to this problem. In developing and evaluating different satellite-based approaches to index insurance, WRMF aims to find new ways forward for the index insurance sector that would hopefully have wider-reaching benefits for agricultural and climate risk management.

Data for index insurance: the challenge

Building on lessons learned from first-hand experiences and internationally recognized research, WRMF identified the limited availability of quality weather and yield data at the village level as one of the main technical constraints preventing index insurance from reaching its full potential. An index insurance product that people can rely on requires both historical and current weather and yield data. Without these data, the design of index insurance becomes challenging and might result in products that are unreliable and subject to excessive levels of "basis risk" (i.e. inaccuracy in matching losses and payouts), which would threaten farmers' immediate economic and food security and cause them to lose trust in insurance.

Even where networks of weather stations are available, there are common challenges, for example: lack of such stations in sparsely populated areas or close enough to the insured area(s); inability of such stations to provide the right quality of data needed to develop insurance indices; unavailability of long-time series of data. Resolving these issues is not as simple as building more of the right kind of stations. Long-term maintenance costs and operating requirements would be significant for the large number of stations needed to cover dispersed populations and to reflect different weather patterns across different terrains. Even with additional stations, the lack of historical data would still represent a challenge for designing and rating index insurance. Furthermore, a detailed, almost complete series of yield data at the village level is usually not available, depend very much on the extent of agricultural research that has been carried out in an area.

Index insurance developers are turning to satellite-based approaches to overcome these challenges. However, despite the significant experience developed in drought insurance for pasture, applications for smallholders' cropping activities are relatively new, and there is a clear need for careful validation and evaluation of such approaches.

The project: an overview

In 2012, with financial support from the Agence Française de Développement, WRMF began implementing an innovative project designed to evaluate the feasibility of satellite-based technology for index insurance to benefit smallholder farmers at the village level. Managed by the team at IFAD, the project "Improving risk management in sub-Saharan Africa: remote sensing for index insurance" aims to contribute to the development of sustainable approaches to index insurance that can help smallholders better manage their risks due to weather, but also other perils. The project, which will run until 2016, is testing the approach in Senegal, with lessons applicable to the entire sector.

The project unites a wide range of different actors working in remote sensing, insurance and reinsurance, aid and development, and agricultural research (see Figure 1). These partners are developing, testing, validating and evaluating a variety of remote sensing approaches to be used as a basis for index structures. The different techniques being tested range from vegetation indices, to rainfall estimates, soil moisture and evapotranspiration. These data sets are either directly integrated into index insurance structures or are first linked with ground observations, such as yield or Start of Season information. Maps of homogenous crop areas and growth patterns based on optical and radar technology are also being developed.

Figure 1. Project partners

Remote sensing
VITO (Technical Coordinator), together with Environmental Analysis & Remote Sensing (EARS), Famine Early Warning Systems Network (FEWS NET), GeoVille, International Research Institute (IRI) for Climate and Society, ITC – University of Twente, and sarmap
Crop monitoring
Senegalese Centre for Agricultural Research (ISRA) together with experts from the International Cooperation Centre in Agricultural Research for Development (CIRAD) and the Regional Research Centre for Improving Adaptation to Drought (CERAAS)
Project Evaluation Committee
This includes, among others: Swiss Re and other reinsurance experts; space agencies NASA, European Space Agency, Italian Space Agency; other index insurance actors such as the Global Index Insurance Facility (GIIF), Index Insurance Innovation Initiative (I4), PlaNet Guarantee; in-country experts from Centre Suivi de Ecologique (CSE), ISRA and CERAAS, as well as leading remote sensing experts from FAO, the EC Joint Research Centre (JRC), WFP, Hoesfloot Spatial Solutions, and the Technical University of Denmark

A farmer in Koussanar. Finding a sustainable approach to index insurance can help smallholders better manage some of their production risks. ©William Dick

The project aims to develop indices that can accurately depict yield loss at the village level due to weather and/or other perils, and which could be used in operational insurance schemes delivered at the micro level, or in more aggregated forms at the meso level.[1]

The research focuses on four sites in Senegal: Diourbel, Nioro, Koussanar and Kaffrine.[2] These Regions of Interest (ROIs) differ in rainfall pattern and risk profile. The project partners working with remote sensing are developing indices to cover losses of maize, groundnut and millet in each of the ROIs. At the same time, ground monitoring of crops is being undertaken to validate accuracy.

Ground monitoring of millet in Kalbiron, Koussanar to help validate accuracy of remote sensing products.
©IFAD

At the end of each crop season, a multi-disciplinary evaluation committee assesses both the technical and operational performance of the methodologies developed, highlighting the opportunities and constraints of each methodology to better understand the feasibility of remote sensing for index insurance. The project will also report on other possible uses for the developed applications and their by-products.

[1] The type of analysis required for index insurance covering smallholder farmers at a micro level is different from that used for aggregated macro-level risk transfer and for other applications of remote sensing for food security, such as Early Warning Systems (based on more wide-scale aggregated crop estimates).

[2] On the basis of lessons learned in 2013, in-situ data collection was increased as of 2014 in Diourbel, Nioro and Koussanar, but terminated in Kaffrine.

The project plans to introduce the most promising methodologies into active index insurance schemes, such as the R4 Rural Resilience Initiative (a joint partnership between WFP and Oxfam America) and IFAD-supported projects and programmes, in order to ensure their adoption by key private and public players in sub-Saharan Africa and sustainability beyond the project's lifespan.

Development organizations and the insurance industry are taking a strong interest in the outcomes of this innovative project, which is filling a critical information gap and addressing a scaling-up constraint. While the project does not aspire to give a final verdict on the use of remote sensing for index insurance, nor to generate a definitive classification of the different approaches and methodologies tested, findings from the project could push further the frontier for the index insurance industry and strengthen smallholder-oriented approaches to risk transfer, risk mitigation and risk management in general.

Remote sensing methodologies

Seven remote sensing service providers (RSSPs) were selected for participation in the project: EARS, FEWS NET, GeoVille, IRI, ITC, sarmap and VITO. The selected RSSPs tested a variety of relevant remote sensing approaches, while concurrently demonstrating their skills and expertise. Each RSSP was guided by the project team on how to develop index insurance structures and encouraged to introduce innovations in product design that would be compatible with the developed methodologies.[3]

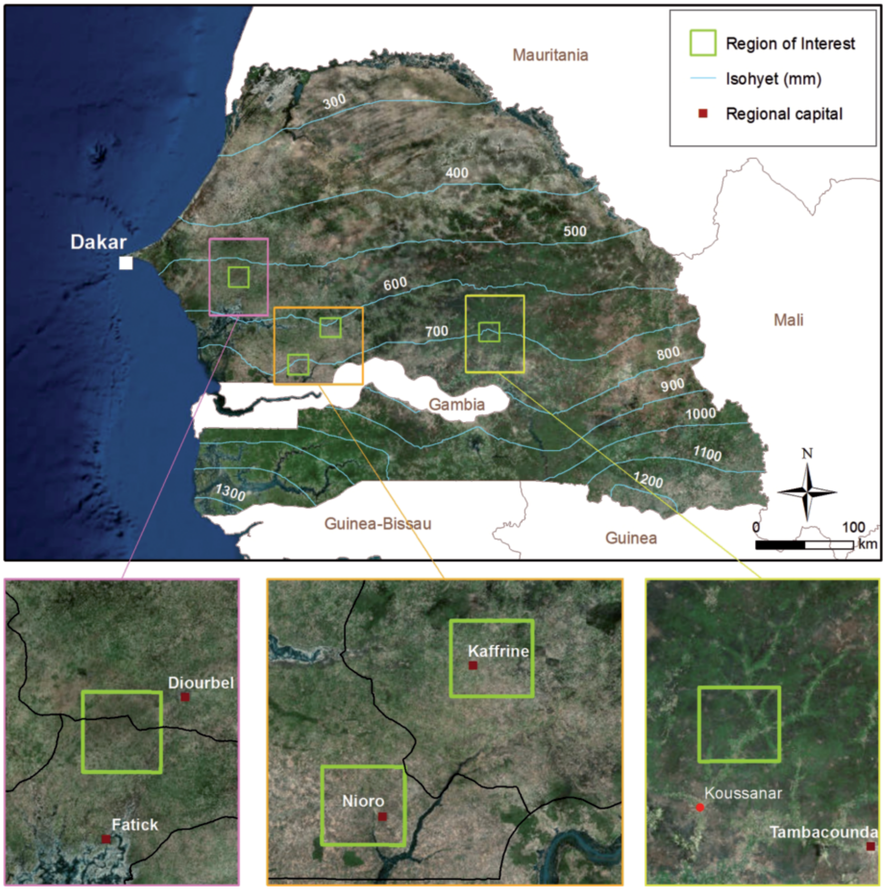
Table 1 summarizes the different types of index products developed by the RSSPs. If sold in insurance, some of these indices would pay out based on the typical expected yield loss due to drought (rainfall-based deficit indices), while others would pay out on expected yield loss caused also by other perils (yield deficit indices). Most of the developed indices are crop-specific, divided into fractions of crop life cycle (vegetative, flowering, yield formation) and calibrated using historical yield statistics (department and village level).

3 This does not include sarmap, which focused on developing a high resolution mask based on SAR data.

Table 1. Overview of remote sensing methodologies

Remote sensing service provider (RSSP)	Type of remote sensing product/approach	Remote sensing data used (including spatial resolution)
EARS	Relative evapotranspiration	MSG-based relative ET (3km*3km)
Geoville	Radar-based estimation of soil moisture Start of Season detection based on Soil Water Index	ERS (50km*50km) resolution and METOP ASCAT (50km*50km and 25km*25 km)
FEWS NET (USGS)	Actual evapotranspiration	MODIS-based ET (1km*1km)
IRI	Rainfall estimates	NOAA-based RFE2 ARC (10km*10km)
ITC	Vegetation indices (NDVI)	SPOT-VGT NDVI (1km*1km)
sarmap	Radar crop maps and Start of Season indicators	CosmoSkyMed data (3m*3m)
VITO	Vegetation indices (fAPAR) Start of Season estimation based on rainfall estimates	SPOT-VGT fAPAR (1km*1km) TAMSAT rainfall estimates (4km*4km)

Type of index and other products	Crop specific indices or generic index?
Estimation of yield deficit	Crop specific
Start of rainy season as basis for an agricultural insurance product	Generic
Estimation of yield deficit	Crop specific
Rainfall deficit	Generic
Estimation of yield deficit and crop mask	Crop specific
Agricultural mapping and detection of Start of Season at the field level	Generic (cultivated land versus non-cultivated), being developed further to distinguish crop type
Estimation of yield deficit	Crop specific



The four Regions of Interest in Senegal: Diourbel, Nioro, Kaffrine, and Koussanar.

Ground data monitoring

The four ROIs, each covering an area of 20 km x 20 km, were selected to represent typical areas producing smallholder annual crops, but exhibiting different seasonal rainfall patterns within Senegal's strong north-south gradient. The selection criteria included existing crop monitoring in the areas and – in the case of Koussanar – the benefit of it being one of the project sites for WFP's R4 Rural Resilience initiative, which includes operational implementation of index insurance. Diourbel, Kaffrine and Nioro are situated within the so-called "groundnut basin" and demonstrate differing but relatively more intensive and well-organized agriculture, whereas Koussanar has less cultivated land and poor food security. Each of the ROIs cultivates groundnut, millet, and sometimes maize, and is exposed to the same risks: dependence on rainfall; production constraints resulting from lack of timely access to quality seeds and other inputs, as well as technology; poor soil quality due to lack of phosphate and deforestation; and loss of crops due to birds and pests.

Contract structures were developed by the RSSPs for each ROI for the purpose of tests, which were carried out during the 2013 crop season. In order to validate and evaluate the performance of selected indices, crop and rainfall monitoring took place in up to 10 fields identified in each of the selected villages in the ROIs. The fields were monitored before, during and at the end of the season, as well as post-harvest. These data were also supplemented by interviews with local farmers and extension officers to gain a thorough qualitative understanding of the areas, including production patterns and techniques, prevalent crop varieties, calendars, risk profile and yield loss history.

Following a review of the 2013 test results, a decision was made to increase the intensity of crop monitoring through larger sample sizes. Accordingly, efforts were amplified in Diourbel, Nioro and Koussanar, while Kaffrine was excluded from the project.

Performance analysis and evaluation

The performance analysis and evaluation processes of the project aim to extract information on the technical and operational feasibility of remote sensing technologies for index insurance, as well as any other potential risk management uses. In its role as the Technical Coordinator, VITO leads the performance analysis exercise, which examines and presents the technical performance of the different remote sensing methodologies using historical field data, validated against the contemporary season ground data.

At the end of each crop season the Technical Coordinator produces a report analysing contemporary season validation and historical performance for new or updated methodologies. The report is used to assist the Evaluation Committee in developing recommendations on the applicability of remote sensing technology for index insurance for smallholders. This evaluation is not limited to the analysis of the performance; it also considers a series of other operational criteria (see Table 2) that will help determine the actual applicability of the methodologies in a wider agricultural and economic context. In this way, the project maintains an "end-user" perspective, i.e. it aims to address the requirements of all stakeholders in operating and maintaining a viable and sustainable system of index insurance covering smallholders.

Table 2. Evaluation criteria

EVALUATION CRITERIA	ASSESSMENT QUESTIONS (sample selection)
Suitability for index insurance (not dependent on testing activities)	
Availability of base data and supplementary data/information	• For what historical period is the base data used for the index development available? • At what level of spatial resolution is data collected? Is it available at the global level, Africa-wide, or only for specific areas and situations? • What supplementary data (e.g., crop calendars, agricultural practices, weather data) is required to effectively implement the methodology?
Cost and sustainability of data acquisition, data processing and product development	• Is the base data free, or does it need to be purchased? • Is the data available in near-real time (few days)? Is the development process labour-intensive, or can it be significantly automated? • What capacity-building is needed to develop processing and index design on a national or regional basis? • Once adapted to a specific area, is the methodology easily scalable elsewhere in Africa, or does it require significant work for each Unit Area of Insurance (UAI) to be covered?
Ownership and transparency	• If the methodology is not proprietary, how technically challenging is it to be replicated/adopted by other institutions? • Regardless of whether proprietary or not, are the processing algorithms available for audit in the event of a dispute? • Would it be technically feasible to transfer the necessary know-how in development of indices to organizations or companies in the countries of implementation?
Performance and suitability	• Do the developed indices only cover drought, or do they capture other perils as well? • Can the methodology discriminate between agricultural and non-agricultural activities (e.g. forestry, pastoralism)? • Can the methodology discriminate between crops? Does the methodology show strengths and weaknesses in specific parts of the crop season? • How complex is the product in terms of explaining its operation to potential clients (for day-to-day operations technical infrastructure and scientific background)? • Do the methodology and its index development have direct spin-off benefits for other end-user applications in agricultural risk management or early warning?

Performance analysis and accuracy (based on test results)	
Historical analysis and calibration	• How do triggered payouts match the recorded losses? • How robust is the contract performance with respect to reasonable changes in the contract parameters? • Is there flexibility of the index to adapt to different vulnerability conditions of the UAI? • Is the methodology able to take into account undergoing long-term fluctuations or changes in local climate?
Analysis of test performance	• Based on the crop monitoring analysis carried out in the test sites, how well has the methodology performed in the definition of the UAIs within the 20 km x 20 km sites? • If losses in the fields have been experienced, have payouts been triggered? • If so, how closely have they matched the losses observed? • Has the methodology shown to be potentially complementary to other developed methodologies? • What seem to be the strengths and weaknesses of the methodologies in the specific testing area?

The performance analysis and the evaluation feedback are assessed by the project team in order to draw lessons and plan improvements. It is anticipated that, after three seasons of development, testing, analysis and evaluation, overall conclusions will be drawn on what remote sensing methodologies can do for index insurance, in which conditions they can operate and what each methodology can realistically be expected to deliver.

2. Findings and lessons learned after first test season

Introduction

While it would be premature to present conclusions after a single test season, it is reasonable and worthwhile to highlight the findings of the first year, and to focus on key lessons learned. With two additional seasons of development, testing and assessment still to be undertaken, these findings are indicative; however, they are already contributing towards better industry knowledge regarding the use of remote sensing for index insurance.

An important contribution that the project is making to index insurance is improving the understanding of basis risk. The project aims to verify how accurate are the different structures developed by the remote sensing methodologies in capturing agricultural losses and, consequently, in highlighting potential levels of basis risk. While basis risk can never be eliminated, the project can contribute to finding new mitigation solutions.

Testing and data challenges

The true performance of remote sensing methodologies for index insurance – the ability to pay out when losses have occurred – can only be tested when crop losses occur. It should be noted that the length of the annual crop cycle limits the number of observations that can be considered significant from an insurance point of view. Such temporal constraints can be partly mitigated by spatially diversifying the test cases; this is why the project is conducting tests in several different sites, and why it may benefit from an even wider geographical scope.

Reliable and significant conclusions on the use of different remote sensing products for index insurance require a significant amount of good quality historical yield data at levels of aggregation matching the spatial requirements of the different methodologies. In developing countries, where this type of index insurance would be applied, suitable data sets are not often available; this creates additional challenges for the project in assessing the performance of the indices. These constraints are being addressed through the project's dedicated crop monitoring activities.

Overall performance of the methodologies

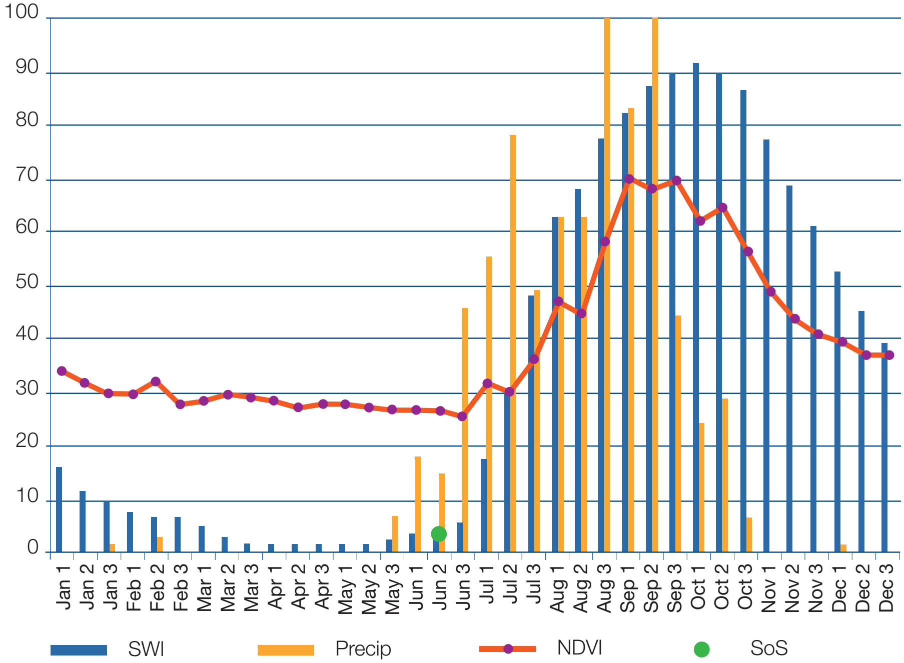
Although the performance of the methodologies has been encouraging, some improvement is needed. The project assessed the historical performance of each remote sensing methodology and index structures proposed by the RSSPs against yield data series ranging from 2001 to 2012, as well as contemporary season validation. The analysis of the historical performance shows that, on aggregate and across all crops and areas tested, the different methodologies were able to perform correctly for the large majority of the observations.[4] While this seems to be encouraging, ideally the design and calibration activities should be able to match all relevant loss events and not generate any payouts in non-loss years. Although RSSPs are not expected to generate structures that are free of basis risk (and, indeed, it is probably technically impossible to do so), they have been encouraged to carry out more accurate work on design and calibration to further improve the performance of the indices.

Farming communities in the test areas did not experience severe crop losses during the 2013 season; project crop monitoring showed that only groundnut yields were slightly lower than average in Kaffrine and Koussanar.[5] Hence, conclusions that can be drawn from the 2013 validation are not as significant as they would have been had losses occurred. Nevertheless, many useful indications on crop behaviour, farming practices, spatial variability of yields and other related issues have been collected during the monitoring activity, providing useful insights. For example, the 2013 validation activity demonstrated the ability of the developed methodologies to detect the actual start of the growing season by comparing SoS estimates derived by remote sensing with field observations compiled by the monitoring institution. In most cases, the timing detected by the methodologies was found to be within the range of the observed SoS periods.

Expanded temporal testing will provide additional data to assess performance, while contemporary crop monitoring data collection has been increased to allow for more in-depth validation and interpretation. Performance will also be enhanced through improvements in the design and calibration of the indices.

[4] These figures consider all tested methodologies, except the one that developed a specific “Start of Season” indicator which is not directly comparable. For the case in point, “performing correctly” means that, for each observation, the deviation between the outcome of the index structures and the expected result is within 15 percentage points.

[5] Planet Guarantee has implemented an index insurance programme for groundnut and maize in Nioro, based on measurements at dedicated network weather stations. Planet Guarantee have made data available on the 2013 performance of the indices designed for these areas and crops. There were some payouts made in Nioro for both maize and groundnut. The results from this programme will be considered in the analysis of the performance of remote sensing indices developed during the project.



One of the processes VITO uses to create an insurance contract is analysing Start of Season estimates based on soil moisture, compared to NDVI and rainfall data.

Crop and area performance

Analysis of the historical performance has yielded other interesting findings – for example, the fact that the methodologies perform differently for different crops. While the methodologies perform effectively for maize, they do better for groundnut, and better still for millet. Similarly, the methodologies perform differently at different test sites. Adding further complexity, the performance of the individual methodologies sometimes differs depending on the particular crop/area combination.

It should be stressed again that these results are still preliminary. However, they do prove the usefulness of a broad-range testing activity that allows the identification of the strengths and weaknesses of the various approaches in different operating conditions. In this respect, setting up similar tests in other areas and in other environments may further enhance the understanding of the specific potential of each of the tools being examined.

Design and calibration of indices

The project has raised awareness among participating RSSPs regarding the needs of index insurance. For some of them, this was the first experience in designing and calibrating index-based insurance products. Several RSSPs have realized that the design and calibration of indices are as important as the capabilities of their remote sensing methodologies, because they significantly influence the performance of the latter. In this respect, there is significant potential for improvement, as some RSSPs have not used all available information for calibrating the indices; incorporating additional ground data made available by the project could improve both design and calibration. None of the RSSPs have had the opportunity to interact directly with local experts; doing so could help improve design-related activities.

Defining Unit Areas of Insurance (UAIs)

Remote sensing provides a spatial zoning tool that makes it possible to segment geographical areas by risk profile and thus identify appropriately sized UAIs. In index insurance, the UAI is a defined area within which all farmers are grouped to receive the same payout rate as determined by the index. The accurate definition of the boundaries of UAIs is therefore critical for smallholder insurance initiatives, which for the purpose of scaling up must find the optimum balance between:

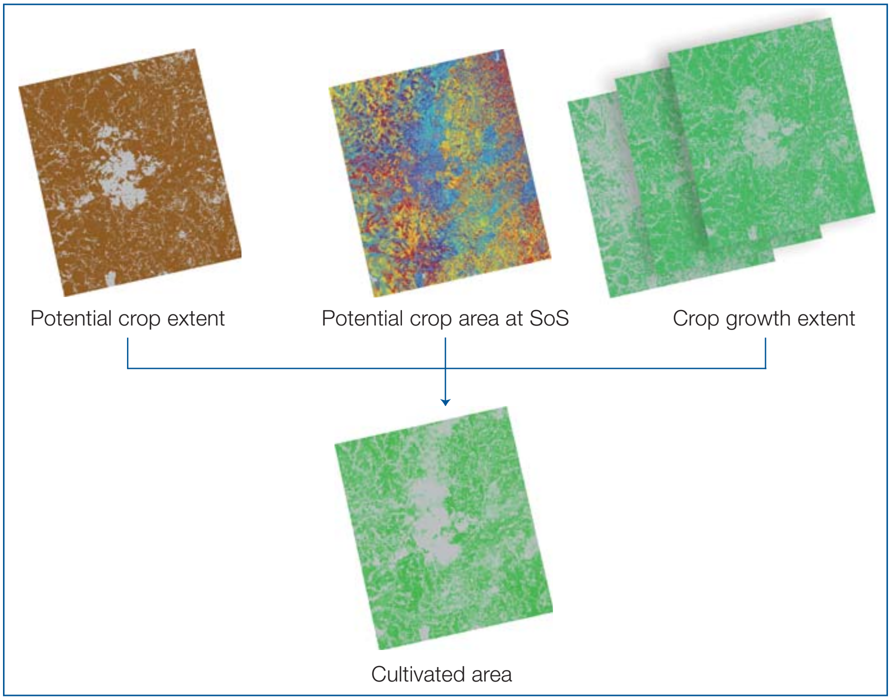
- the desire to minimize the spatial size of the UAI, so as to theoretically minimize the potential for "spatial basis risk" – i.e. variation in yields within the UAI; and
- the fact that very small UAIs could create administrative challenges to insurers or insurance scheme managers, as indices would need to be individually calibrated at very local levels and farmers would have to be allocated to very small UAIs at the time of enrolment.

The project tasked the RSSPs with the definition of optimal UAIs in the test areas. Evidence collected in the first round of tests reinforced the need for a spatial zoning tool as a means of supporting an effective scaling up of index insurance programmes. In forthcoming tests, the RSSPs have been asked to devote even greater attention to demonstrating the zoning capacity of the methodologies they have developed.

Crop maps and masks

Crop maps and masks[6] can increase the performance of some of the indices. Two of the RSSPs – ITC and sarmap – have been developing maps and masks with the objective of identifying land use and also exploring the possibility of differentiating between various crops. The initial results of the first testing activities seem to be promising, particularly with regard to mapping based on radar technology.

[6] A crop mask is based on coarse resolution data and expresses a percentage of a crop represented in a pixel. It thus leads to better exploitation of mixed pixels in coarse resolution imagery and is increasingly used in regional and global crop monitoring systems.



COSMO-SkyMed Product - ©ASI - Agenzia Spaziale Italiana (2014). All Rights Reserved. COSMO-SKYMED images, from the Italian Space Agency, are enabling sarmap to identify Start of Season and map cultivated areas.

These tests have provided useful indications on how to improve crop monitoring and are helping to identify the most efficient possibilities in terms of costs and benefits of the potential mapping tools. Some of the project methodologies, in particular those that estimate the field performance of crops (e.g. approaches based on vegetation indices and evapotranspiration), could generate more effective results if they were able to segment areas to be monitored. Combining crop masking with another methodology might enable the development of more crop-specific outcomes, although it would also add considerable complexity to the data processing carried about by the RSSPs to create the index insurance contract structures.

3. Next steps

Following a review of the 2013 test results and the crop monitoring findings, some adjustments were made to the activities of the RSSPs in 2014, including improvements to and fine-tuning of the methodologies and index structures.[7] In particular, there has been an increased emphasis on the ability of each methodology to segment geographical areas on the basis of their risk profiles and thus identify UAIs of appropriate size. Evaluation of this aspect is also informed by the high level of variation in yields among individual farmers, as shown by crop monitoring.

A smallholder farming family in Koussanar. The project is investigating innovative remote sensing technologies for index insurance to benefit more smallholders. ©William Dick

The role of crop maps and masks, and how to best combine them with other indices, will be further investigated as one of the measures that could improve the performance of specific methodologies. The project will also consider integrating different methodologies in order to make improvements or achieve more.

[7] Analysis of the 2014 season performance and lessons are still to be carried out at the time of publishing.

The continuation of the project within the existing ROIs will be extremely valuable in terms of understanding the ground-level variability of yield outcomes in different years in each of the monitored villages, indicating whether such variability can be detected by remote sensing. The first year of crop monitoring indicated a high spatial variation of yields between areas and even within the same area. Information regarding the spatial variation of yield outcomes both in normal years, but particularly in adverse years (when insurance payouts are expected), is highly relevant to building sector knowledge on basis risk and how it should be mitigated. Furthermore, as the technical findings of the project unfold, there will be an emphasis on how these findings relate to insurer end-user needs (as highlighted in Table 2). Insurers, as the likely principle contact point with clients and managers of the insurance underwriting, also need to be equipped with operational and financial/business knowledge of remotely-sensed index insurance, including associated data and processing costs, and the required technical and operational capacities.

The project will continue with the cycle of development, testing and crop monitoring for two more crop seasons. Analysis of results and findings after each season will help make improvements along the way and contribute to the overall conclusions that will be shared with the sector after activities come to an end in 2016.

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ISBN-978-92-9072-561-9

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