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AGRIALLIS

Science for Agriculture and Allied Sector: A Monthly Magazine

Volume 8, Issue 8

Article Id
AL04542

# THE ROLE OF EXTENSION PERSONNEL IN REMOTE SENSING-BASED INFORMATION AND CROP INSURANCE IN EMERGING ECONOMIES

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Agriculture in emerging economies is increasingly exposed to climate variability, extreme weather events, pest outbreaks, and production uncertainties, making effective risk management essential for ensuring farmers' livelihoods. Remote sensing technology has emerged as a transformative tool by providing timely, accurate, and cost-effective information on crop conditions, acreage, vegetation health, soil moisture and disaster impacts through satellite and unmanned aerial vehicle (UAV) imagery. These advancements have significantly improved crop insurance programmes by enabling faster damage assessment, yield estimation, and transparent claim settlement. However, the successful implementation of remote sensing-based crop insurance depends not only on technological innovations but also on the effective dissemination and interpretation of information at the grassroots level. Agricultural extension personnel play a pivotal role in bridging the gap between advanced geospatial technologies and farming communities. They create awareness about insurance schemes, facilitate farmer enrolment, interpret satellite-based advisories, validate field conditions through ground-truthing, assist in claim documentation, enhance farmers' digital literacy and provide continuous feedback to research institutions and insurance agencies. Their involvement strengthens farmers' trust in technology-driven insurance systems while promoting informed decision-making and climate-resilient agricultural practices. Despite considerable progress, several challenges remain, including inadequate digital infrastructure, shortage of trained extension personnel, limited technical capacity, connectivity issues and basis risk associated with satellite-based assessments. Strengthening extension systems through regular capacity building, digital skill enhancement, institutional coordination and integration with remote sensing platforms is essential for improving the efficiency, transparency and inclusiveness of crop insurance programmes. A strong partnership between extension services, remote sensing technologies, and insurance institutions can significantly enhance agricultural resilience, reduce production risks, and support sustainable rural development across emerging economies. This integrated approach will contribute to climate-smart agriculture and long-term food security. The article emphasizes the indispensable role of extension personnel in achieving these outcomes.

Agriculture in emerging economies remains heavily exposed to weather variability, pest outbreaks, and climate shocks, and smallholder farmers who make up the majority of producers in South Asia, Sub-Saharan Africa, and parts of Southeast Asia and Latin America carry a disproportionate share of this risk. Crop insurance has emerged as a central instrument for stabilizing farm incomes, but conventional loss-assessment methods built on manual crop-cutting experiments and field visits are slow, costly, and prone to dispute. Advances in satellite and unmanned aerial vehicle (UAV) remote sensing now allow yield and damage estimates to be generated at a fraction of the cost and time, and are increasingly embedded in national insurance programs across the developing world.

Yet technology alone does not reach the farmer. Agricultural extension personnel, the frontline officers who interpret science for practice, remain the critical link that converts satellite-derived indices and portal-based claims data into decisions farmers can act on: when to enrol, how to interpret an alert, and how to pursue a claim. This report examines the concept of remote sensing in agriculture, the state of crop insurance in emerging economies, and the specific roles extension personnel play in making remote sensing-based insurance systems functional, equitable, and trusted at the village level.

## Concept of Remote Sensing

Remote sensing refers to the acquisition of information about the Earth's surface without physical contact, typically through sensors mounted on satellites, aircraft, or UAVs. In agriculture, optical sensors capture reflectance in visible and near-infrared bands to compute vegetation indices such as the Normalized Difference Vegetation Index (NDVI), which correlates with crop vigor and biomass, while synthetic aperture radar (SAR) penetrates cloud cover to detect soil moisture, flooding, and crop structure regardless of weather. These data streams are combined with weather station records, soil information, and, increasingly, machine-learning models to estimate crop area, monitor phenological stages, detect stress, and forecast yield at scales ranging from a single field to an entire district.

Two features of remote sensing make it especially relevant to insurance in emerging economies. First, coverage: a single satellite pass can observe thousands of villages simultaneously, something manual field sampling cannot match. Second, the pace of infrastructure growth has been rapid; commercial Earth observation constellations have expanded from a handful of new satellites launched annually earlier in the decade to well over a hundred per year by the mid-2020s, improving the frequency and resolution of imagery available for agricultural monitoring.

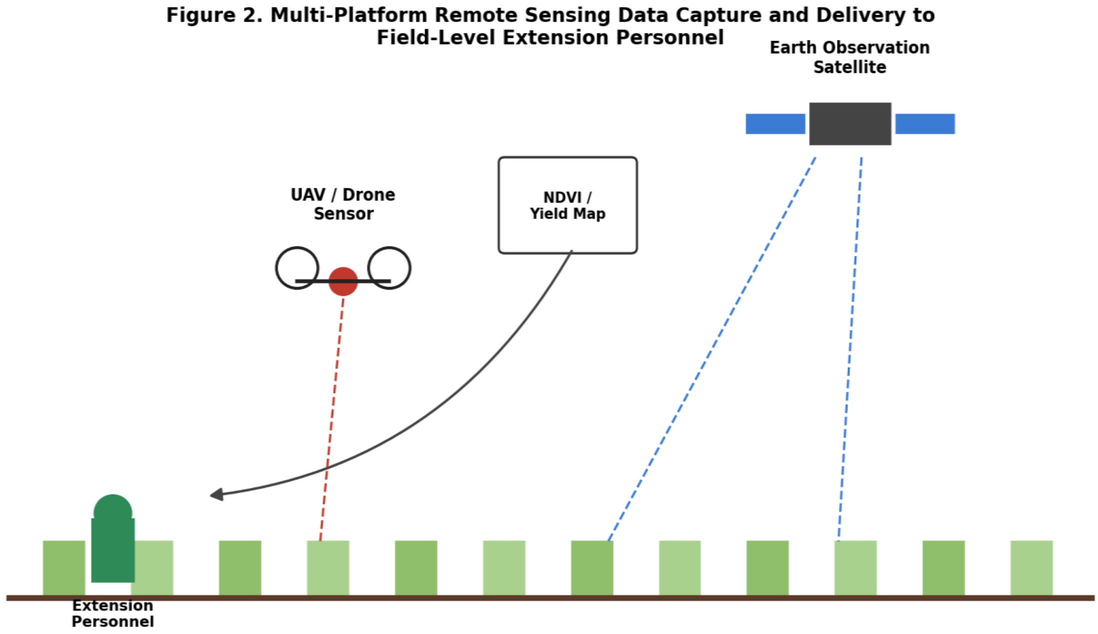


**Fig. 2:** Multi-platform remote sensing data capture (satellite and UAV) and its delivery pathway to field-level extension personnel who translate raw imagery into farmer-facing advisories.

## Crop Insurance in Emerging Economies

Comparable index-insurance and remote-sensing-linked products have grown in Sub-Saharan Africa and parts of Latin America and Southeast Asia, often supported by development partners, though most remain smaller in scale than India's program and continue to face challenges around basis risk, the gap between an index's estimate of loss and a farmer's actual loss on the ground. A systematic review of the literature on satellite-based agricultural index insurance underscores that while remote sensing lowers the cost of loss verification, its accuracy is highly dependent on local crop classification, ground validation, and the institutional capacity that surrounds the technology.

**Common Program Features**

**Table 1:** Common structural features of remote sensing-linked crop insurance programs in emerging economies.

| Feature | Description |
|---|---|
| Area-yield basis | Claims are triggered by shortfalls against a threshold yield computed for a defined insurance unit rather than an individual farm. |
| Technology blending | Satellite/UAV-derived yield estimates are combined with traditional Crop Cutting Experiments (CCEs) rather than fully replacing them. |
| Subsidized premiums | Government contributions keep farmer-paid premiums low, typically a small fixed percentage of the sum insured. |
| Digital portals | Centralized platforms (e.g., National Crop Insurance Portal in India) integrate enrolment, land records, weather data, and claims processing. |
| Extension-mediated enrolment | Field officers and bank/cooperative intermediaries remain the main channel through which smallholders learn about and join schemes. |

## Role of Agricultural Extension Personnel

Extension personnel occupy the interface between the technical apparatus of remote sensing-based insurance and the lived reality of smallholder decision-making. Evidence from climate-smart agriculture research consistently finds that the quality and trust associated with face-to-face advisory contact, not mere access to information, is what drives farmer awareness and adoption of new practices and products. Their contributions can be grouped into the following functions.

**Table 2:** Core functions performed by agricultural extension personnel within remote sensing-based crop insurance systems.

| Function | Extension Personnel Contribution |
|---|---|
| **Awareness creation and enrolment** | Explaining scheme rules, insurance units, cut-off dates, and how satellite-based yield estimation affects claim calculation, in local language and through farmer group meetings. |
| **Interpretation of technical outputs** | Translating NDVI maps, weather alerts, and modelled yield figures from portals such as WINDS or YES-TECH dashboards into actionable guidance farmers can use for sowing, irrigation, or claim decisions. |
| **Ground-truthing and data quality support** | Assisting with Crop Cutting Experiments, verifying crop-type maps against actual field conditions, and flagging discrepancies between satellite estimates and observed losses. |
| **Grievance redressal and claims facilitation** | Helping farmers document losses, understand claim rejections, and navigate the appeals process when remote sensing-based assessments are disputed. |

| | |
|---|---|
| **Capacity building and digital literacy** | Training farmers and para-extension workers (e.g., Krishi Sakhis, lead farmers) to use mobile apps and SMS-based advisories linked to insurance and weather platforms. |
| **Feedback to technical agencies** | Relaying field-level observations back to modelling agencies (e.g., MNCFC, ISRO-linked institutions, national meteorological services) to improve model calibration. |

## Practical Applications Applications

I. Pre-season advisories combining satellite soil-moisture data with extension-led guidance on sowing windows and crop choice.

II. In-season stress alerts (drought, waterlogging, pest-favorable conditions) pushed via SMS or mobile apps, with extension officers following up in person for high-risk cases.

III. Post-harvest yield reconciliation, where extension staff support validation of modelled yield against sample harvests to reduce disputes at claim settlement.

IV. Farmer field schools and demonstration plots that build trust in remote sensing-derived recommendations before scaling to insurance-linked decisions.

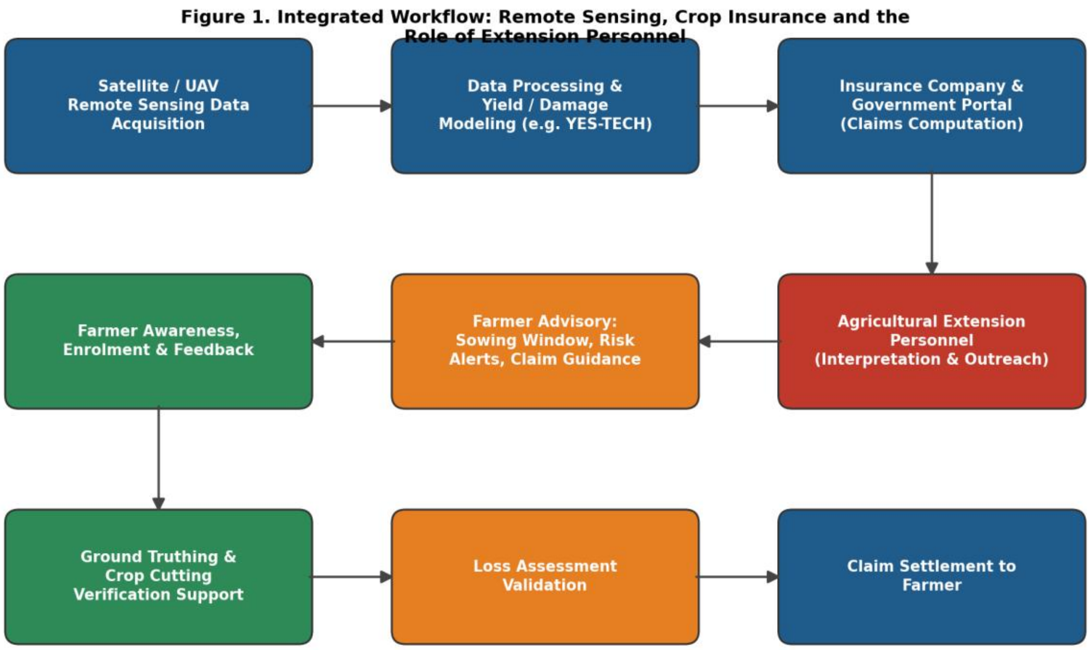


**Fig 1:** Integrated workflow linking remote sensing data acquisition, technology-based yield modelling, and the mediating role of extension personnel through to claim settlement.

## Case Studies

### India: PMFBY, YES-TECH and WINDS

India's PMFBY has piloted and scaled the Yield Estimation System based on Technology (YES-TECH) since 2023, mandating a minimum weightage for technology-derived yield in claim calculations for paddy and wheat, with reported implementation across pilot districts without major disputes in the initial Kharif 2023 rollout. A complementary Weather Information Network and Data Systems (WINDS) initiative is establishing hyper-local automatic weather stations to strengthen the data layer feeding these models. District and block-level extension officers, along with Common Service Centres and bank correspondents, remain the primary channel through which farmers understand and access these digital layers, and government guidelines explicitly assign States responsibility for adopting satellite and UAV remote sensing for crop area estimation, yield disputes, and loss assessment.

The Government of India, in partnership with development agencies, has also worked to widen access to credit and insurance for small, marginal, and women farmers, an effort that depends substantially on the last-mile trust that extension networks provide, since digital yield dashboards alone do not resolve farmer skepticism about automated claim decisions.

### Sub-Saharan Africa: Index Insurance and Advisory Ecosystems

In Malawi, satellite-based damage mapping supported rapid post-disaster assessment following Cyclone Freddy in 2023, illustrating remote sensing's value for both routine index insurance and emergency response. More broadly, research across Ghana, Nigeria, Kenya, and South Africa finds that public extension agents remain the most frequently used advisory channel for smallholders, ahead of mobile platforms, though effectiveness depends heavily on advisors' own training in climate and remote-sensing-derived information; studies in South Africa's Limpopo province, for instance, found that a majority of extension practitioners lacked formal training in climate-change-related advisory content, constraining their ability to translate remote sensing outputs into farmer guidance.

## Cross-Cutting Observations

- Programs that pair remote sensing infrastructure with a well-resourced extension cadre report fewer claim disputes and faster settlement.

- Where extension capacity is thin or undertrained in digital tools, farmers report low awareness of adaptation and insurance options even when technical infrastructure exists.
- Hybrid information ecosystems, extension agents working alongside farmer groups, mobile applications, and radio, tend to outperform any single channel used alone.

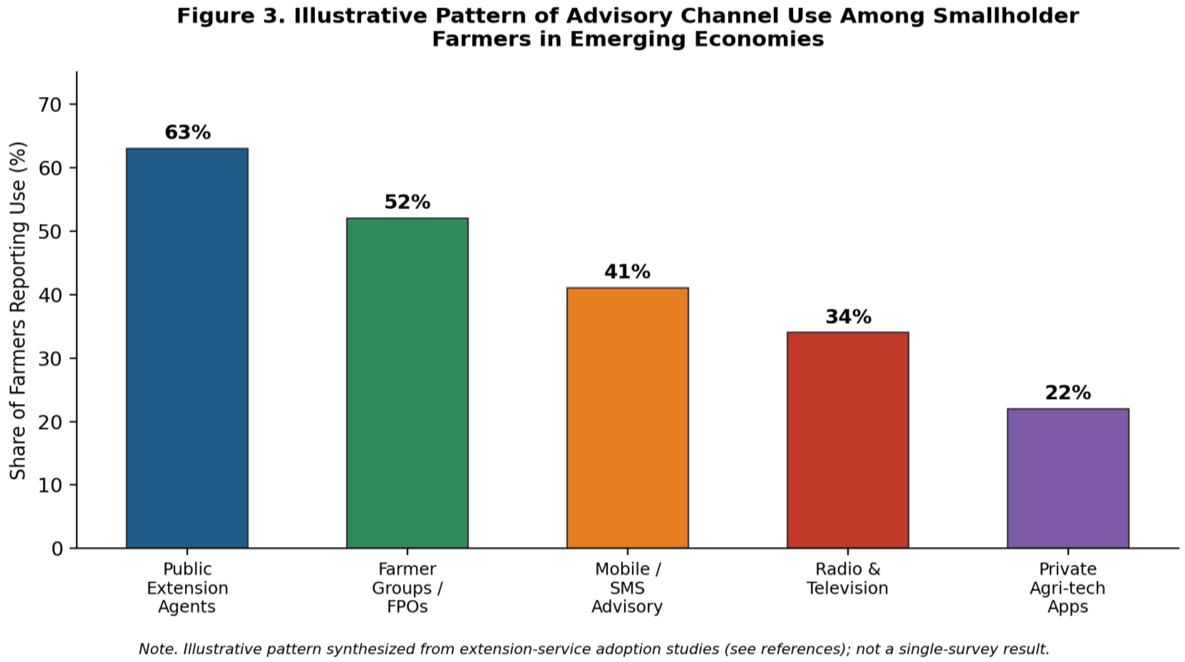


**Fig. 3:** Illustrative pattern of advisory channel use among smallholder farmers, synthesized from extension-adoption studies cited in this report; figures are indicative rather than drawn from a single survey.

## Challenges

**Table 3:** Principal challenges constraining the extension-mediated delivery of remote sensing-based crop insurance.

| Challenge | Description |
|---|---|
| **Extension staff shortages** | Low extension officer-to-farmer ratios in many emerging economies limit the frequency and depth of in-person contact needed to build trust in remote sensing-derived decisions. |
| **Digital and technical skill gaps** | Many field officers have not received formal training in interpreting satellite indices, weather-model outputs, or insurance dashboards. |
| **Basis risk and farmer distrust** | Discrepancies between modelled yield/damage estimates and a farmer's actual field experience can undermine confidence in both the technology and the extension officers who communicate it. |
| **Infrastructure and connectivity** | Poor rural internet and mobile connectivity constrain the delivery of real-time alerts and dashboard access in remote areas. |

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|---|---|
| **Institutional coordination** | Fragmented responsibilities among meteorological agencies, insurance companies, technology implementation partners, and extension departments slow feedback loops. |
| **Language and last-mile translation** | Technical outputs must be reformulated in local languages and farmer-relevant terms, a task that is resource- and skill-intensive at scale. |

## Future Prospects

The rapid expansion of commercial Earth observation constellations is expected to further increase the spatial and temporal resolution of agricultural monitoring available to insurance programs, while artificial intelligence and machine-learning-based yield models continue to mature. Realizing the benefit of these advances for smallholders will depend on parallel investment in extension capacity: structured training curricula on remote sensing interpretation, digital advisory tools tailored for low-bandwidth settings, and stronger integration of extension feedback into model calibration. Emerging approaches such as delinking insurance subsidy disbursement from state government timelines, expanding hyper-local weather networks, and building para-extension cadres (for example, community-based lead farmers and women's agricultural collectives) point toward more resilient, farmer-trusted systems in the years ahead.

## Conclusion

Remote sensing has fundamentally changed what is technically possible in agricultural insurance, allowing yield and damage estimates to be generated faster, more objectively, and at a scale manual methods cannot match. But technology alone cannot deliver trust, comprehension, or equitable access. Agricultural extension personnel remain the indispensable human infrastructure that converts satellite data into decisions farmers can act on, mediates disputes, and channels field-level realities back into technical systems. Strengthening extension capacity, training, staffing, and digital tools, should therefore be treated as a core investment alongside satellite infrastructure itself if remote sensing-based crop insurance is to fulfil its promise for smallholders across emerging economies.

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