Role and Prospective Impact of Technological Interventions in the Spread of Agricultural Insurance through PMFBY and Beyond

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This paper aims to address the issues faced during the evolution of PMFBY and its spread by means of technological advancement. This paper will focus on the following points,

- *A methodology to use information from satellite-based remote sensing to allow improved liability and compliance monitoring and better loss-adjustment and claims management.*
- *Better understanding of the tools necessary to develop damage assessment systems.*
- *Information on crop stress and damage and risk assessment.*
- *Reduction of claim-settlement period.*
- *New technological developments, such as the combination of IoT devices and multi-sensor satellite or UAV images with different spectral, spatial and temporal resolution.*

Key Words: PMFBY, Risk Assessment, Claim Settlement Period, Multi-Sensor Satellite Image, IoT Devices

1. Introduction

In India, agriculture continues to be the major employment sector as more than 50 percent of the population is dependent on farming. The risks associated with the agriculture industry, specifically in India, are aggravated by various factors, ranging from weather variability, frequent natural disasters, uncertainty of good crop production, low market pricing, lack of effective rural infrastructure, and market information asymmetry that reduces the efficacy of risk mitigation instruments like credit lending and **Agricultural Insurance** (specially **Crop Insurance**). The above-mentioned factors not only pose risks to the livelihood and incomes to the farmers but also

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hinder the whole agriculture sector in becoming part of the solution to the problems faced by agricultural labour.

The major problems lie, among others, in the complexity of the agriculture sector in terms of farms size, mixed crop plantation, and drastic climatic changes. These have led to the disengagement of banks and other financial institutions with financing of rural/agricultural financing, since there is lack of profitability. The remoteness of the rural clients and poor financial networks increases the cost of doing business in these types of areas. India's rural transformation and national economy are dependent on the agriculture sector, for which fiscal and monetary interventions are required to ensure security of the farming community, and also to generate steady supply of income, generate savings, and investment. The grossly under-funded Indian agriculture sector provides ample opportunities to banks, insurance and reinsurance companies to provide sustainable solutions to farmers by providing the necessary and timely capital to come out of the poverty trap and get insulated from the frequent income shocks.

Some of the other immediate challenges faced by the farmers in India are the depleting groundwater resources, climate change, increase in the frequency of extreme events like droughts, floods etc., lack of fair and timely compensation for losses incurred, lack of transparency in fixing the fair prices for the various farm produce, and difficulty in having easy access to markets. Other than weather-related issues, lack of proper insurance schemes and unfocalized insurance index developed by insurance companies are the major issues due to which fair insurance premiums are not charged at the time of need. These are compounded by the already existing problems. like debt burden, lack of access to scientific agricultural practices, dwindling farm holdings and institutional apathy in providing easy access to markets.

But the Government of India is currently emphasising and encouraging the use of technological advancements in agriculture to tackle these problems faced at the time of spread and implementation of the PMFBY scheme.

2. Proposed Solution

Preventive measures can be taken to minimize crop / yield losses by early detection of pests and diseases. It can also provide the precise location of crop-damage area along with the intensity of the damage by geo-tagging of hand-led images. Models based on satellite imagery and geo-tagging images from IoT sensors will provide solutions for the validation of insurance claims and timely settlements.

A. Preventive Measures:

(a) Pest and disease diagnosis and early detection. Crop-health analysis, stress analysis, drought prediction for decision on insurance premium.

(b) Using models, built with current ground data and satellite images, one can estimate the previous years' trends and history of yield losses and damages.

(c) Based on the estimates of previous year's yield, one can determine a suitable action plan, decide on premium amounts, and region-specific corrective measures.3

B. Post Damage:

(a) Identify the intensity of damage with precise locations (co-ordinates) and acreage of crop damages via satellite imagery

(b) Claim validation, based on coarse and fine resolution obtain satellite data.

In order to obtain the model for crop damage assessment and ascertain the degree of damage, ground truthing can be done with hand-held devices. The model with both coarse resolution and high resolution satellite data can be obtained using such ground truthing. Once trained, coarse resolution satellite data can be used for the first level damage screening, followed by region-specific high resolution analysis.

3. Project Milestones

Agriculture fields are widely distributed all over the states in the country, but mostly in rural areas. It is time-consuming and costly to get updated information about the micro level ground situation by reaching each and every agricultural field and understand the difficulties and also monitor them on regular basis for agricultural insurance purpose.

This problem can be solved by a single dashboard. And the dashboard will be a one-window solution to overcome this limitation. It will encompass a wide-coverage area by remotely sensed satellite information tool with different kinds of indices and analysis on regular time-intervals and it will help to monitor the current ground situation, identify the cultivated crops by type of land area in a single-window solution. It will also contain historic information to compare the current situation, which will lead to make accurate decision consequent to the forecast, thus providing the solutions for insurance-related issues.

4. *Motive*

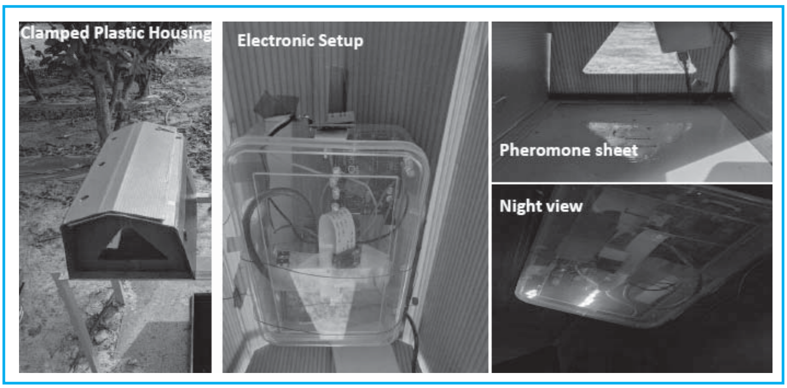
Merging the information extracted from satellite images with the IoT sensors is the distinctive feature of the proposed services. Precision farming uses remote sensing to detect variability in the soil and crop conditions. Detail-rich imagery helps actively manage fields and reduce crop inputs. Mitigate risk with localized zone management; lower costs to control and treat insects, diseases and weeds by eliminating them when they start to sprout. Regulating inputs and scheduling harvest can maximize the yield. Early diagnosis of disease can lead to take preventive action before it's too late. It also minimizes yield lose. Several IoT devices and hand-held imaging solution can detect pests and diseases on almost real-time basis from the ground level. Any infected plant can be traced by this technology. After identification of any anomaly it can provide A.I based early warnings for the Insurance agencies as well as the farmers to take care of the crops and to avoid further losses from pests and disease.

A. IoT Devices

1. IoT Devices for Pest Detection

There are several IoT devices to attract the pests which have infected the crop. These devices have pheromone sheets that are likely to attract the pests that infest a particular crop. The LED array in these devices attract specific target pests and then glue them to the

Figure 1
Components of IoT Devices for Detection Purpose



device. After that the camera captures the images of insects and uploads the images for analysis and generation of statistics regarding the target pests and their counts. The end-user obtains alerts on the arrival of specific target pests and related time statistics through AI on cloud. The weather casing house for the installed field device makes it functional for all weather conditions. Figure 1 presents the picture of various components of this kind of IoT devices.

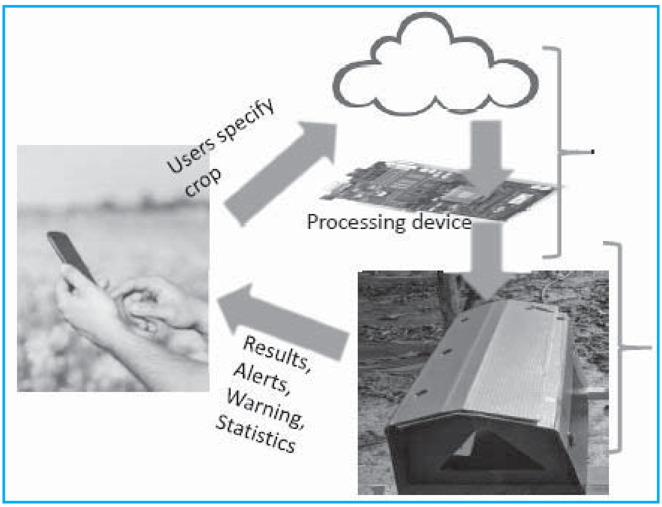
These devices are associated with highly optimized, configurable and customizable classification engines that can be deployed on the device itself to perform all the computations locally and instantly. The algorithms are optimized to consume very small quantity of power by the device. Only the final results are relayed to the users, thereby achieving very low bandwidth requirements. Figures 2 and 3.

Various eminent experts in the area of plant pathology have contributed to develop crop specific models. It has also been tested on various crop fields like wheat, rice, pulses, millets, drip-irrigated horticulture crops, plantation crops, like tea and coffee, poly-house farming and so on.

It also has the setup to run it on solar power. The solar power directly supplies power to the device and simultaneously charges the power bank to make it self-sustained during the nights as well.

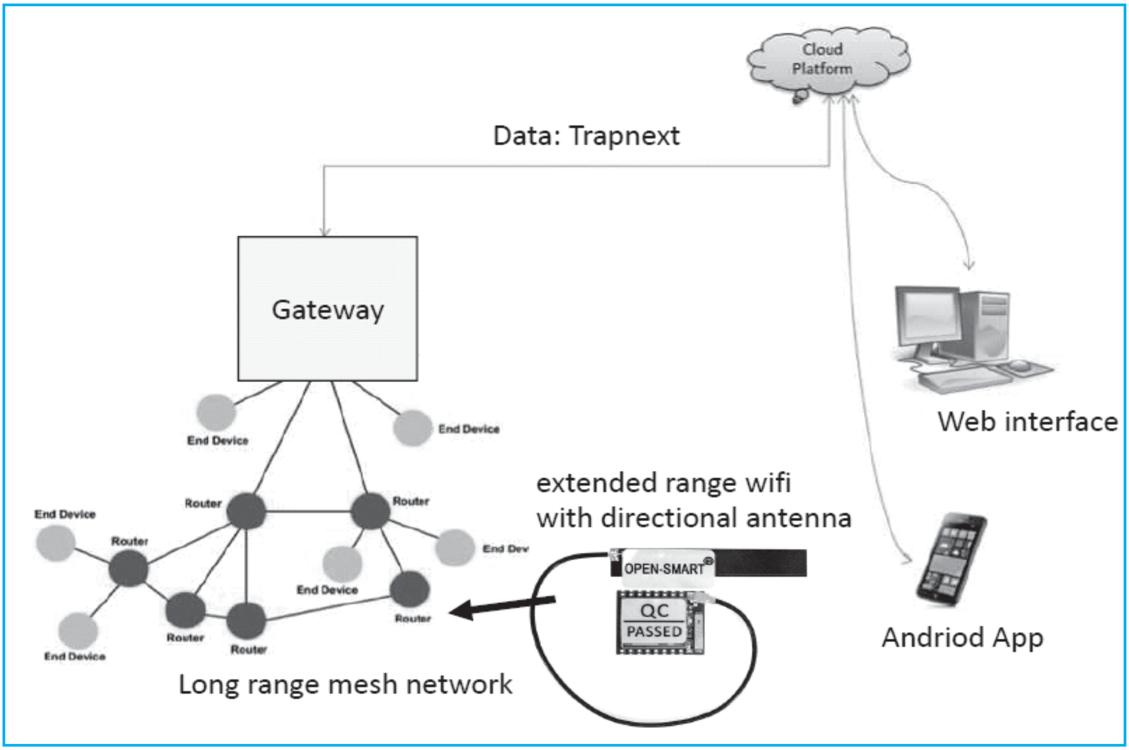
Figure 2

Device Image Processing, Image Classification and Robust Communication



- This equipment downloads customized machine learning classifier codes for specific crops, locations and climate-specific pests.
- Entire image capture, processing and classification happens in the device; only the final results are communicated to the farmer, thereby limiting dependency on the bandwidth.

Figure 3
Cloud-based Long Range Communication Architecture in Real Time

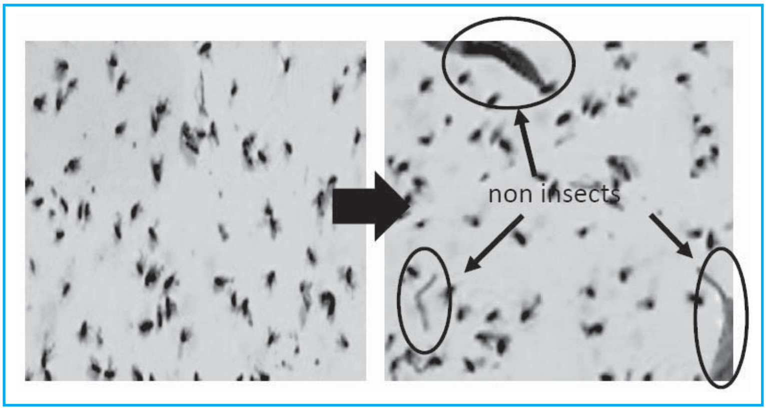


Distinguishing the various pest by Artificial Intelligence

- Features
  - Large training set was created by artificially combining segmented images of spurious elements like leaf parts, stem parts.
  - For minimizing the false positive, resulting from such artifacts, the resulting composite image were segmented to isolate different blobs (insects and non-insects).

- The isolated blobs were classified using a trained deep network to distinguish between pests and non-pests.
- Overall ~98% accuracy was obtained for the classification. More challenging cases are being examined.

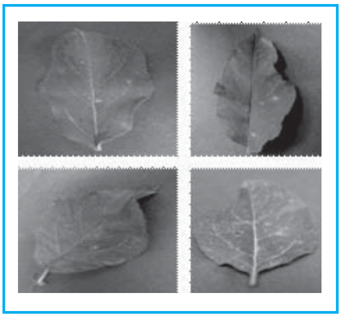
Figure 4
Distinguishing Pest and Non-Pest Elements in the Picture



2. Hand-held Imaging for Disease Detection

In case the pests have already infested and damaged the crop, then the farmers can identify the pests by clicking the image of the crop and uploading it in the app. The image will be processed and analyzed on the server through a model that is trained and developed by using thousands of images of different crops through artificial intelligence. The result will be displayed on the screen instantly and recommendations of remedial measures will also be indicated.

Figure 5
Infected Leaves



Hence a fully automated system will benefit the insurance agencies to identify the problem areas on timely basis so that further action can be taken to avoid yield losses. It can also be used to validate the claim location and identify the quantum of damage for hassle free settlements. User-friendly android-based interface for geo-tagging the field images of diseased plants can be prepared. The geo-tagged images will be directly uploaded to the cloud. Insurance agency can obtain the images and information of disease type and predict the projected lose.

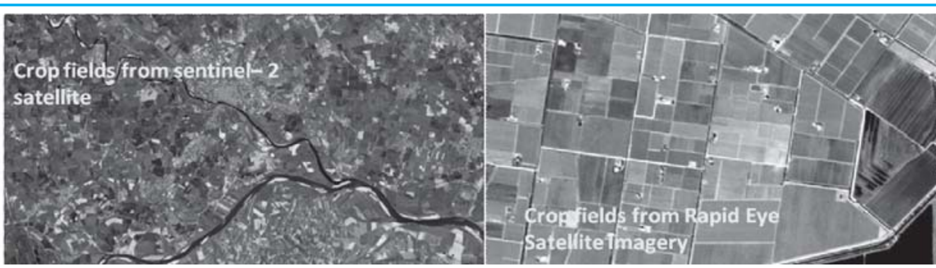
B. GIS and Remote Sensing

Food security for a rapidly increasing population in our country is getting critical, and the use of precision agriculture has transformed farming. But much as agriculture is now big business, small farmers and farms, often in developing countries like us, are just as critical to world food markets and to the health of our traditional economies. In the field of agriculture, satellite imagery has revolutionized food production and supply chain management with the development of precision farming. It offers precision information of agriculture fields to the insurance company's access to make timely decisions using detailed geospatial information that can assist guidance on premium policy making, validating the claims of the farmers and timely reimbursement of claims. Satellite images plays a major role in the:

- Image processing.
- Vegetation health monitoring.
- Site-specific crop yield management.
- Near infrared imaging capability.
- Terrain feature identification and change monitoring.

Figure 6

Corse / Moderate Resolution Satellite Images



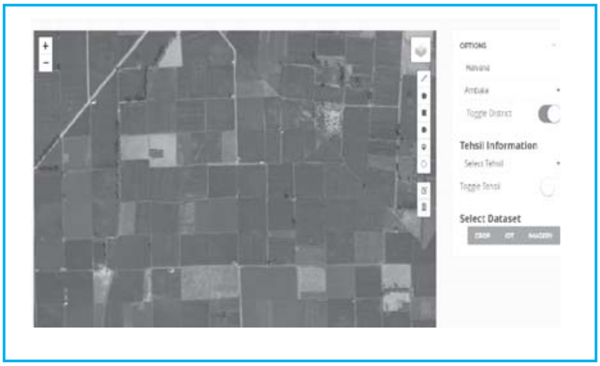
Role of Satellite Images in Agri-Insurance:

- Agricultural crop Monitoring.
- Yield Forecasting and lose prediction.
- Crop type identification and acreage of cultivated crop with geo-graphical co-ordinates.
- Water Resources for agriculture.
- Cross loss assessment: Damage identification, acreage of damage and intensity of damage.
- Crop growth monitoring and stress level identification.
- Affected crop region monitoring.

❑ Satellite for crop monitoring is the technology which facilitates real-time crop vegetation index monitoring via spectral analysis of high resolution satellite images for different fields and crops which enables to track positive and negative dynamics of crop development. [2] The difference in vegetation index informs about single-crop development disproportions that speaks for the necessity of additional agriculture works on particular field zones [4]- that is because satellite crop monitoring belongs to precision agriculture methods.

Figure 7

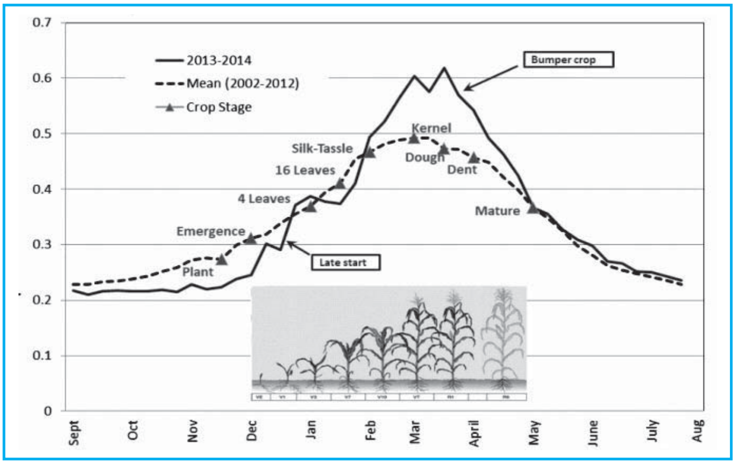
User Interface of our dashboard



Various remote sensing techniques are commonly used nowadays in providing information about land cover, as well as the condition of the land in terms of resources. Additionally, other remote sensing techniques such as satellite imageries play a significant role considering the rapid changes in landscape following the adoption of large scale development in agriculture. With the application of the appropriate remote sensing techniques, one can capture information on changes in the growth of plants be it structural or chlorophyll changes. As such, some of the approaches you can adopt in this case include the use of airborne and satellite images for the purpose of classifying crops, examining their viability and health, as well as monitoring the farming practices. The below figure represents the NDVI monitoring.

Figure 8

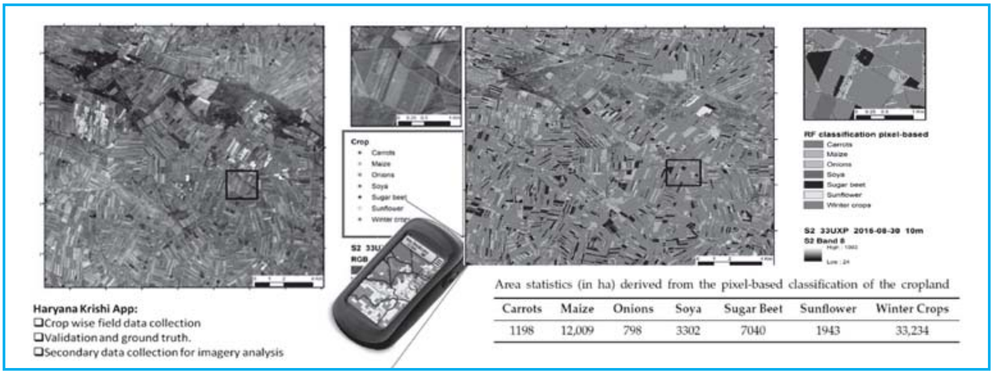
NDVI based monitoring for a specific time period



- **Crop type identification and the acreage of cultivated crop (Crop- Classification).**

  Crop type identification is the basis of crop acreage estimation and plays a key role in crop production prediction and food security analysis. However, the accuracy of crop type identification using remote-sensing data needs to be improved to support operational agriculture-monitoring tasks. New method integrating high-spatial resolution multispectral data with features extracted from coarse-resolution time-series vegetation index data is proposed to improve crop type identification accuracy. Crop growth features, including peak value, date of peak occurrence, average rate of green-up, and average rate for the senescence period can be extracted from time-series Moderate Resolution Imaging (Sentinel-2) normalized difference vegetation index (NDVI) profiles and spatially enhanced to 20 m resolution using resolution merge tools based on a multiplicative method to match the spatial resolution of sentinel. A maximum likelihood classifier (MLC) can be used to classify the Sentinel and merged images. Hence field data (GPS data) is also mandatory for classification training set and testing the classification accuracy. High level cropping information can be extracted using moderate resolution imagery. But high resolution (0.5m) resolution is needed to extract plot level information. Multispectral (NIR with RGB) can be fused with 0.5m pan data for achieving optimum resolution.

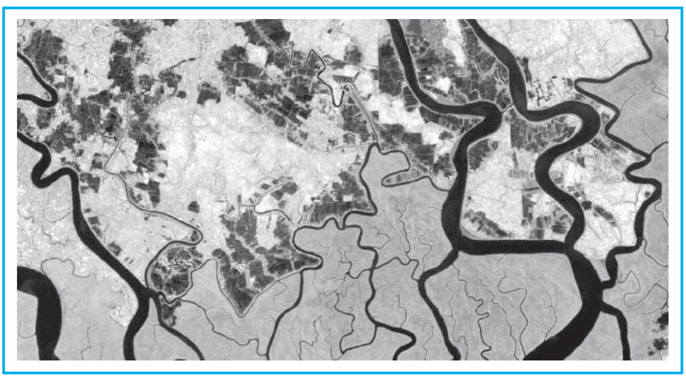
Figure 9
Crop classification and acreage calculation.



- **Identifying source and amount of water for agricultural fields**

Rain-fed farming is the natural application of water to the soil through direct rainfall. In India most of the agricultural land is still rain-fed. Surface water bodies like ponds, lakes and canals are also the main source of water of the agricultural lands. Irrigation is the artificial application of water to the soil through various systems of tubes, pumps, and sprays.

Figure 10
Water Resources for agriculture



Irrigation is usually used in areas where rainfall is irregular or dry times or drought is expected. There are many types of irrigation systems, in which water is supplied to the entire field uniformly. Irrigation water can come from groundwater, through springs or wells, surface water, through rivers, lakes, or reservoirs, or even other sources, such as treated wastewater or desalinated water. As a result, it is critical that farmers protect their agricultural water source to minimize the potential for contamination. As with any groundwater removal, users of irrigation water need to be careful in not pumping groundwater out of an aquifer faster than it is being recharged. Natural ground flow paths of Rain water during monsoon which is the natural source of water for agricultural lands and it can also be used to recharge the ground water for agriculture. Hence check dam or water storage can be proposed on the flow paths for automated recharge of water for cultivation in dry season. There are various indices like NWI, NDWI and also landuses to identify the surface water whicy are being used for agriculture. Surface water monitoring can also been done be done by satellite based remote sensing. Hence flow accumulation, run-off etc can also be used for identifying natural re-charge of ground water.

- **Damage Analysis:**

The estimation of the agricultural crops damages using satellite images and technologies, improves the quality and cost effectiveness of the derived information, by

(l) Increasing the objectivity of the methodologies.

(2) Reducing the cost of the classical method.

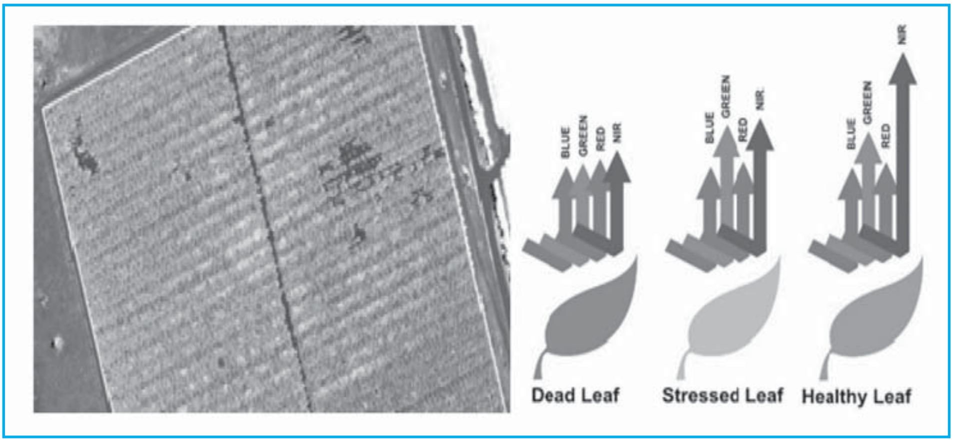
(3) Increasing the confidence of the farmers in the estimation and

(4) Increasing the scope of overall monitoring by the insurance companies.

Figure 11
Stressed Crops

Taking into consideration the significant economic impact of erroneous estimation in classical method, satellite imagery-based crop monitoring should be taken into serious consideration for the significant economic impact on farmer's income and on the policy of the Agricultural Insurance organizations. On the other hand, merging high technological tools like satellite images and IoT sensors creates in the sector of crop damages estimation, a powerful tool for real time analysis. NDVI is correlated with the % damages in various communities and for different crops.

Figure 12
Crop Damage Identification

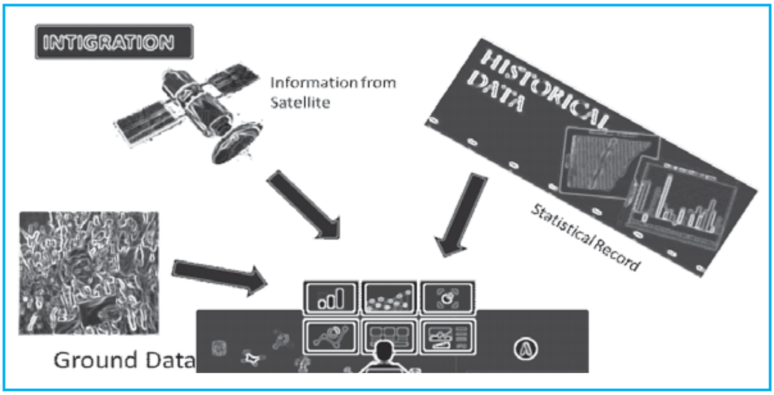


Using the IoT based solution and handheld imaging we can built a model for the analysis of damage due to pest and disease where field ground truthing can be derived from the IoT sensors. Combining IoT information with moderate and high-resolution satellite imagery will play vital role for validating degree of damage with précised location wise information which will ease up premium policy and claim settlement.

- **Model Building:**

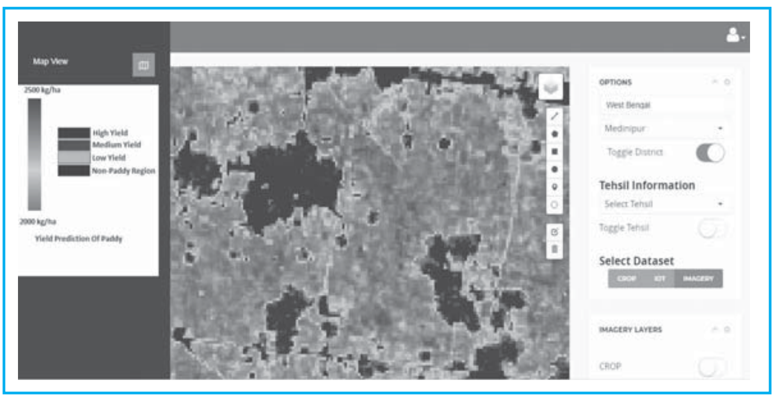
Probabilistic model can be built by integrating statistical historical information with GIS analysis, based on satellite-based imagery and spatial analysis. These models are very useful for Premium estimation, govt. policies, and corrective measures.

Figure 13
Predictive model combining Historical data, satellite data and field-based information.



- **Estimation of Yield**: For the government as well as insurance industry it is important to keep track of disaggregated crop conditions and losses on a real-time basis. It serves several purposes such as satisfying demands from reinsurance industry about the probable losses, targeting of CCEs for better loss assessment, making informed decisions and planning for claim volume, and better preparedness for settling claims after crop harvest. Such information is also very useful for making mid-season on account payments to the insured when they need compensation the most rather than waiting for the claim settlement after the harvest of the crop.

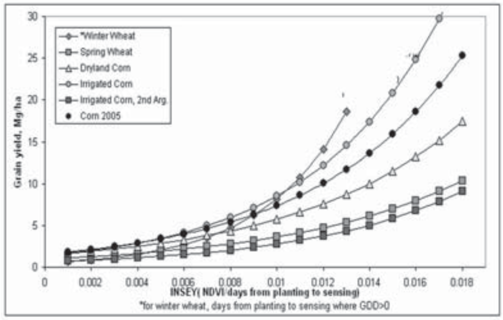
Figure 14
Prediction of Yield on dashboard



In particular, remotely sensed vegetation indices (VIs) such as the Normalized Difference Vegetation Index (NDVI) can also be used for Yield estimation by establishing the co-relation between historical data and the NDVI ranges of crop fields.

Figure 15

NDVI vs Yield



- **Identification of stressed crop using vegetation indices**

  Agricultural production is directly co-related with the crop health. Plants chlorophyll content level is different between healthy and stressed crops and chlorophyll contain can be observed using certain vegetation indices through satellite imaging as well as by drones. Most of the satellite images provide NIR bands for obtaining vegetation analysis. Difference in NIR reflectance can be used for distinguishing healthy and unhealthy crops. Using GIS technology, we can observe the exact location of occurrence of plant stress and the level of stress. This will propose a better approach to yield estimation as well as transparent settlement for the insurance claims

Figure 16

Stress Monitoring

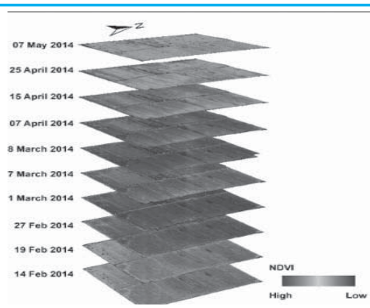
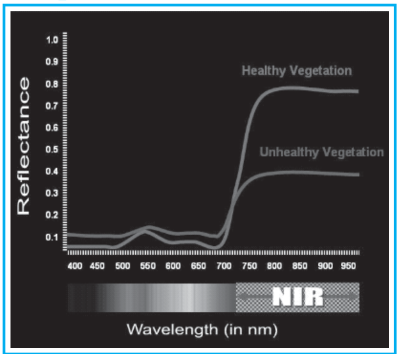


Figure 17
Comparison for NIR reflectance

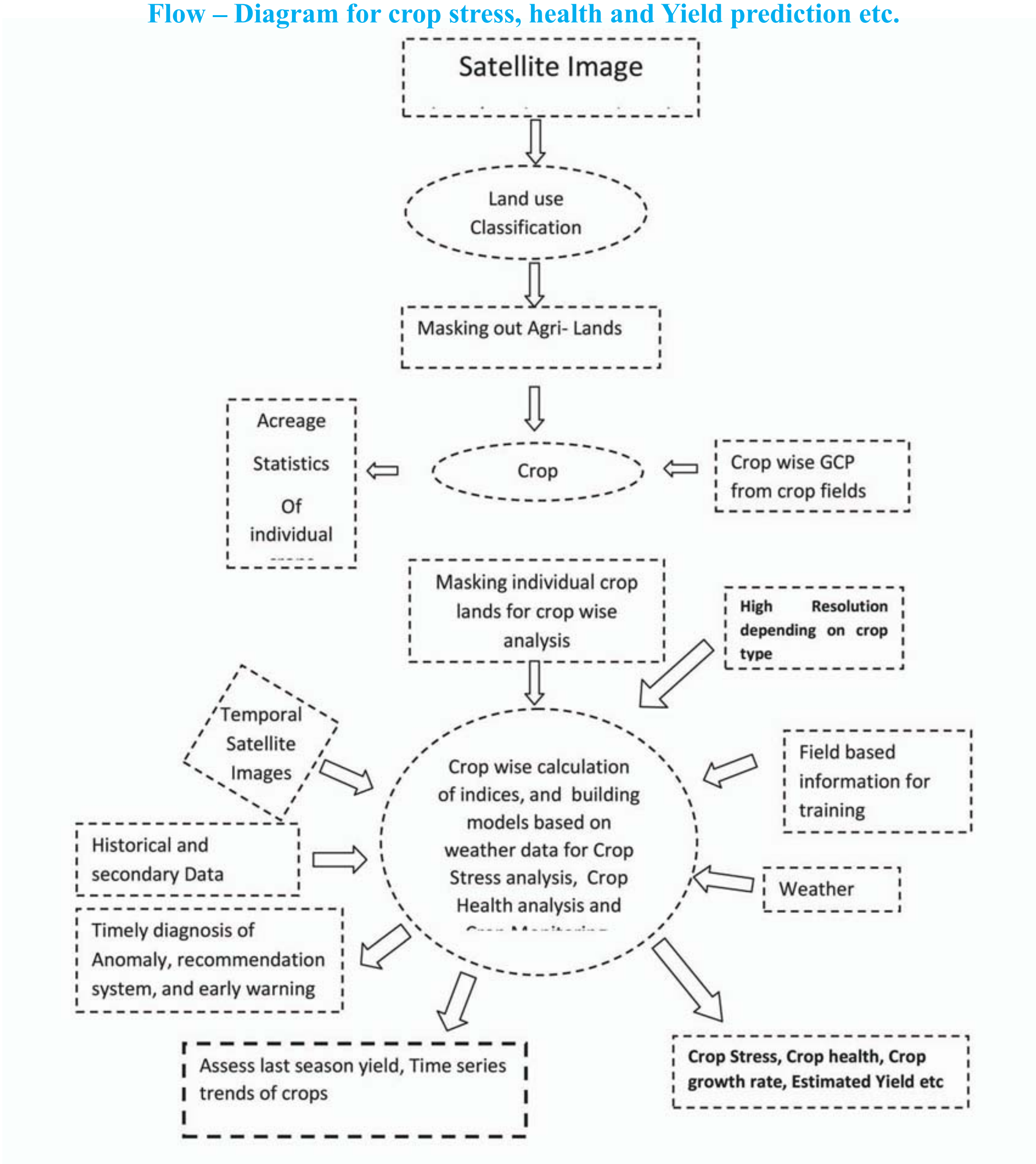


- **IoT**
  - i) Installation of Pest controlling IoT devices, data collection and integration with weather data to build predictive model and early detection model.
  - ii) Use of pre-trained handheld imagery for disease diagnosis.
  - iii) Integration with weather data.
  - iv) Generate predictive model for target crops.
  - v) IoT sensed data can also be used for ground truthing satellite-based health/damage analysis and building model to obtain past years trend.
  - vi) Ground validation for damage due to weather can be done using overview images.
  - vii) Ground validation for disease, pest related damage can be done using close-up image.

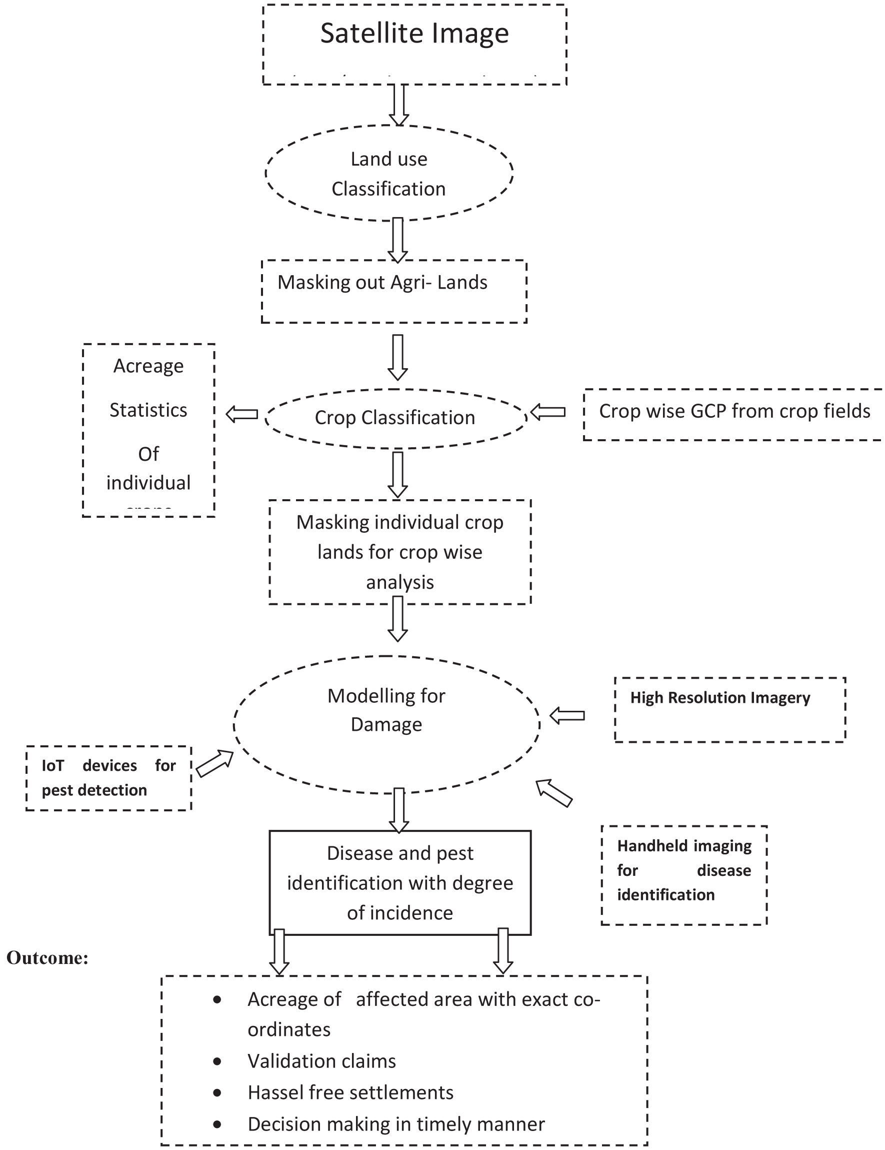
- **GIS:**
  - i) Geo-referencing and radiometric correction of Satellite imagery.
  - ii) AOI- extraction.
  - iii) Land use classification for identifying Agricultural land
  - iv) Field data collection and GCP collection.
  - v) Crop classification.
  - vi) Vegetation Indices based analysis like NDVI, EVI, SAVI etc. for identifying crop stress, crop health etc.
  - vii) Combining secondary statistical data and the vegetation indices from temporal data to obtain Yield estimation, crop growth rate etc.
  - viii) Building predictive model on vegetation indices and historical information.

ix) Using higher resolution imagery Identifying damage and degree of damage and validating model by ground truth data from IoT devices and Handheld imaging.

Flow – Diagram for crop stress, health and Yield prediction etc.



Flow diagram for Damage Analysis:



❖ **Field Survey**

- Field data needs to be collected across well distributed area, stratified by samples of crop types for feeding as training set to the classifier model to perform image classification for identifying acreage, crop type and crop stress. Field survey is also needed for validation of classifier model. So, ground staff deployment is needed for Sample GCP collection and also for collecting various secondary data for analysis. Historical data may also be needed from field if it is not available (explain).

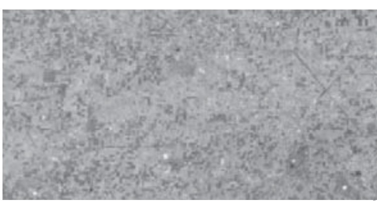
- Co-ordinate based sample information from fields are also needed for identification and analysis of crop specific stress and damage with intensity as parameter."

❖ **Platform:**

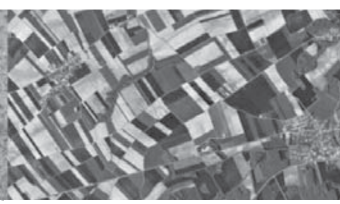
- **Satellite Images:**

a) Low or Moderate resolution imagery: Sentinel - 2 Imagery

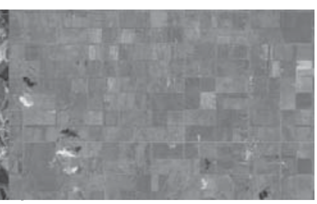
b) High Resolution Imagery: Multispectral Imagery (NIR + MS) with 0.5m pan



Low Resolution Satellite Images (Sentinel Satellite)



High Resolution Satellite Images (0.5m fused with pan)



Moderate Resolution Satellite Images (5m multi-spectral)

Sl no.	Satellite Name	Minimum Special Resolution	Spectral Resolution	Minimum AOI in sq km.	Price / Sq km
1.	Sentinel	20m	8 bands	N/A	Free
2.	Rapid Eye	5m	5 bands	3500	$2/sq km
3.	Superview - 2	0.5	5 bands	25 sq km(Archive data) 100 sq km (Fresh Acquired)	$19/ sq km
4.	Skysat	0.8	5 bands	Not specified till now	$14.5 /sq km
6.	Quick bird	0.6	5bands	25 sq km(Archive data) Fresh Acquired images are not available now.	$17.50 /sq km
7.	Worldview -2/3	0.5	5 bands	25sq km (Archive data)	$17.50/sq km
8.	Worldview -2/3	0.5	5 bands	100 sq km (Fresh Acquired)	$27.50/sq km
9.	Worldview -2/3	0.5	8 bands	25sq km (Archive data)	$19 / sq km
10.	Worldview -2/3	0.5	8 bands	100 sq km (Fresh Acquired)	$29 / sq km

High level to Micro Level Accuracy

- Course or Moderate resolution satellite scan can extract high level information.
- Using Higher resolution we can achieve plot level information and it also increase accuracy of analysis

❖ **Plausible solution for the problems faced, in the spread of Agricultural Insurance:**

a) Total cultivated crop and acreage identification

b) Early detection of loss for preventive action

c) Yield estimation and loss prediction

d) Pest and disease Tracking

e) Damage estimation

f) Historic data on insurance

g) Validation on crop insurance claim and settlement

5. *Conclusion*

The constraints map illustrates that in most cases, farmers face multiple constraints holding them back from investing, disproving the bottleneck model in this context. However, once a coherent set of minimal, but key elements, including insurance is in place, small holders will be able to steadily improve their yields and potentially expand their production. Whether they increase the area under cultivation, diversify into high-yield/higher-risk crops, or invest into better or more farms, farmers will benefit with higher and secured net incomes. This should be easier to evaluate than the benefits of protection (in the sense that farmers don't have to selloff productive assets in the aftermath of severe weather crises), which will only materialize infrequently.

The Indian crop market is unique in many ways. To encourage and maintain capacity in the Indian crop insurance market, it is important that there is more data and risk transparency as well as confidence that risks of moral hazard and adverse selection are being minimized by the processes set up in PMFBY such as mandatory use of technology.

The science and technological backbone behind the efforts of Government and Insurers can definitely be a differentiating factor. Since the technological interventions can provide accurate, customizable services beyond what is already offered by the government, these approaches are on its way to making an impact by improving the quality of information that farmers, and agricultural insurers, need to plan for a fruitful harvest.

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