YIELD ESTIMATION SYSTEM BASED ON TECHNOLOGY (YES-TECH) UNDER PMFBY

Manual for Implementation

Mahalanobis National Crop Forecast Centre
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Preface

Pradhan Mantri Fasal Bima Yojana (PMFBY), being implemented in the country from 2016, has many positive features compensating for multiple risks throughout the crop season. The Department of Agriculture and Farmers Welfare (DA&FW), Ministry of Agriculture and Farmers Welfare, Government of India, is the nodal agency for executing PMFBY. The operational guidelines for smooth implementation of PMFBY were documented in 2016 and revised in 2020 and made available to all the stakeholders (www.pmfby.gov.in).

Crop yield estimates of the Insurance Units (IUs) for the current and past years form the basis for crop loss assessment and indemnity payout. Crop yield estimation is done by carrying out Crop Cutting Experiments (CCEs), the traditional system of manual yield measurements in randomly selected field plots for each crop in each IU. Major limitations of CCE based crop yield estimation include (a) limited number of measurements, (b) time-consuming process, and (c) vulnerable to human errors.

DA&FW has taken up many initiatives to improve crop yield estimation procedures ever since the launch of PMFBY. Technology development agencies of both Government and Private sectors have been engaged for developing new yield estimation methods using various datasets and models through pilot studies.

The objective of these pilot studies was to generate reliable & scalable modelled-yield estimates for paddy and wheat crops at IU level. These studies were conducted during 2019 and 2020 for both the *kharif* and the *rabi* seasons for selected crops and districts across different agroclimatic zones of India. After detailed evaluation, Expert Committee recommended **five approaches** for **national-wide rollout** for yield estimation **for paddy and wheat** crops from the 2023 crop season onwards.

Towards introducing and catalysing large scale adoption of technology-based yield estimates in PMFBY system for crop loss assessment, DA&FW has conceptualised a special initiative i.e., "Adoption of a Yield Estimation System based on Technology (YES-TECH)" under PMFBY. YES-TECH advocates the blended use of modelled and CCE yield estimates for insurance claim assessment from 2023, **for paddy and wheat**. In this connection, an expert committee has been constituted to prepare guidelines for the implementation of YES-TECH.

The expert committee consists of the following Members

S. No	Name of Expert	Designation
1	Dr. C. S. Murthy, Director, MNCFC	Chair
2	Dr. Rajendra Prasad, Director, IASRI (ICAR)	Member
3	Dr. Bimal Bhattacharya, Group Director, SAC (ISRO)	Member
4	Dr. Karun Kumar Choudhary, Head, Crop Monitoring Division, NRSC (ISRO)	Member
5	Dr. Paresh Shirsath, Scientist BISA-CIMMYT	Member
6	Dr. Maheswaran, R. Asstt. Prof. IIT Hyderabad	Member
7	Dr. Sunil Kumar, Asst. Comm. DA & FW	Member
8	Commissioner Agriculture Maharashtra	Member
9	Director of Agriculture, Odisha	Member
10	Dr. Sunil Dubey, Deputy Director, MNCFC	Member Secretary

The committee has organised several consultations to develop the current YES-Tech document. The purpose of this document is to provide **comprehensive guidelines and support to States for implementing technology-based yield estimation** procedures under PMFBY. The important elements of the report are brief description of recommended procedures/models of yield estimation, standard Operating Procedure for implementing the models, mentor agencies to support states, empanelment guidelines for selecting implementing agency, and model tender document for selecting an implementing agency. The Expert Committee strongly believes that this report is useful to States and Implementing Agencies for implementing YES-TECH from the 2023 crop season for paddy and wheat crops.

Chair of the Committee

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1. Introduction

Globally, agriculture is exposed to multiple hazards leading to frequent crop losses. As a result, crop insurance has become an indispensable risk management tool in the agriculture sector. Better management of agricultural risks is one of the important strategies to address the current challenges of food security, income security, and climate resilience in Indian agriculture. Increasing crop risks coupled with low growth and outreach of crop insurance signifies the huge potential for crop insurance in India. Therefore, a robust system of crop insurance is the need of the hour to reduce the impact of covariate risks in agriculture and promote innovations and investments in the farming sector.

Pradhan Mantri Fasal Bima Yojana (PMFBY) being implemented in the country from Kharif 2016, is an area-yield insurance contract that has many positive features to compensate for multiple risks during the entire life cycle of the crop season. The use of technologies viz. remote sensing, mobile and data analytics is mandatory for the effective implementation of the scheme. The Department of Agriculture and Farmers Welfare (DA&FW), Ministry of Agriculture and Farmers Welfare, Government of India, is the nodal agency for executing PMFBY in the country.

Area-yield insurance is a yield guarantee scheme over the specified area. It adopts an area approach defining the Unit Area of Insurance (IU), generally a group of villages called Gram Panchayat. Crop yield estimates of the IU for the current and past years form the basis for crop loss assessment and indemnity pay-out. A certain per cent, 70%, 80%, or 90% of the average yield of the past five best out of seven years of an IU called Threshold Yield (TY) is guaranteed for the current year. Actuarial premium rates are determined at the district level for each crop based on the IU's past risk profiles in the district. The current year's yield shortfall from the TY of the crop in the IU is applied to the sum insured for calculating the payouts (www.pmfby.gov.in).

Crop yield estimation is done by carrying out Crop Cutting Experiments (CCEs), i.e., manual yield measurements at a randomly selected limited number of field plots for each crop in each IU. The limited number of measurements and their proneness to subjectivity have become major constraints in generating reliable yield estimates. As a result, the estimated yield of an insurance unit tends to be biased leading to disputes and delays in claims settlements. Thus, the challenge in the area-yield crop insurance in India continues to be improving the crop yield estimation system.

Technology interventions in the form of using satellite data and mobiles to improve crop yield estimation are largely recognized and promoted. Various limitations in the current system of crop yield estimation in the insurance units along with ways and means to improve the system by using satellite, mobile, GIS technologies, and data analytics were well documented. DA&FW has taken up many initiatives to improve crop yield estimation procedures ever since the launch of PMFBY in 2016 (www.pmfby.gov.in). Technology development agencies of both Government and Private sectors are currently developing new yield estimation methods using various datasets, models, and analysis techniques for improving crop loss assessment in crop insurance.

During the past seasons (2016-2022) of kharif and rabi, DA&FW started engagement with around 50 Tech agencies/experts/researchbodies (Government/private; national/international) and rigorously started conducting pilot studies for GP level yield estimation through several innovative technologies/data like high spatio-temporal resolution remote sensing data, Unmanned Aerial Vehicle (UAV), Advanced intelligent crop simulation models, Artificial intelligence/machine learning, IoT, Soil, Weather & Crop data, Picture based Analysis, Advanced Statistics, etc. to assess the outcome and findings for taking decisions which helps in deciding the best available methodology/strategy for accurate yield estimation at GP level.

The objective of the pilot studies was to generate reliable & scalable technology-based yield estimates for paddy and wheat crops at the smallest administrative unit, i.e., Gram Panchayat. These studies were conducted during 2019 and 2020 for both the *kharif* and the *rabi* seasons for selected crops and districts across different agro climatic zones of India. After detailed analysis, **five approaches** were recommended by the Expert Committee for the **national-level rollout** of technology-based yield estimation **for the paddy and wheat** crops from the 2023 crop season onwards.
Towards introducing and catalysing large scale adoption of technology-based yield estimates in PMFBY system for crop loss assessment, DA&FW has conceptualised a new initiative i.e., "Adoption of a Yield Estimation System based on Technology (YES-TECH)" under PMFBY. YES-TECH advocates the blended use of modelled and CCE yield estimates for insurance claim assessment from 2023, **for paddy and wheat**. In this connection, an expert committee has been constituted to prepare guidelines for the implementation of YES-TECH.

1.1. The rationale behind the YES-Tech initiative

The following developments in technology solutions in crop insurance have led to the conceptualization of the YES-Tech initiative

- Results of pilot studies on technology-based yield estimation for paddy and wheat crops are promising as observed by the Expert Committee constituted by DA&FW.
- Results of the models implemented by other agencies like NRSC (ISRO) and other agencies are already published in peer reviewed international journals.
- Increasing acceptance of technology-based yield estimation by states and other stakeholders
- Proactive steps taken by some of the states like Maharashtra and Madhya Pradesh to adopt technology-based yield estimation

During the National Level workshop on the implementation of Technology Initiatives under PMFBY held on 13th Sep 2022 in New Delhi and 8th National Review Meeting at Kochin in 20-21 October 2022 and NLMC meeting at Delhi in November 2022, the proposal of nationwide implementation of technology-based yield estimation for paddy and wheat crops was widely discussed with stakeholders and the same has been welcomed by a majority of stakeholders.

1.2. Scope of this document

The purpose of this document is to provide comprehensive guidelines and support to States for implementing technology-based yield estimation procedures under PMFBY. There are five sections in this document namely

I. Brief description of recommended procedures/models of crop yield estimation along with YES-Tech implementation frame work
II. Standard Operating Procedure for implementing the models
III. Mentor Institutions/Organizations to support the states
IV. Empanelment guidelines for selecting implementing agency
V. Model tender document for selecting an implementing agency

2. Brief description of recommended models for crop yield estimation and YES-Tech implementation framework

Based on use cases reported from states, scientific research published, and expert committee recommendations on pilot studies, the following five approaches were identified for crop yield estimation covering paddy and wheat crops under YES-TECH initiative of PMFBY;

- Semi-physical model
- AI models
- Crop simulation models
- Ensemble models (AI/ Crop Simulation/ Semi-physical etc.,)
- Parametric index of crop performance (Indirect approach)

2.1. Semi-physical model

This method is based on Radiation Use Efficiency (RUE) model proposed by Monteith, 1977. This model is based on the bio-chemical process of plant–light absorption for photosynthesis, radiation use efficiency, stress factors, accumulated biomass, and grain yield. It is recognized as a better approach than simple empirical modelling. Its strength lies in adopting a process-based framework with limited parameterization.

Critical elements of the RUE model application that impact the accuracy of yield estimates are summarized as under.

- Precise information on crop variety, planting, and harvest dates
- Empirical derivation of FAPAR with NDVI
- Derivation of water stress and temperature stress factors

Temperature and water stress are the two important limiting factors and quantifying these two parameters at local scales like insurance unit remains a big challenge. This model would result in potential yield rather than actual yield if the stress factors are not accounted using right data and technique. The model cannot be applied for part of the season because constant RUE is applicable only when the entire crop-growing season is considered. Availability of cloud-free moderate resolution (10-30m) NDVI and LSWI datasets throughout the crop season may not be possible. Most of the research reported on this model adopted coarse resolution data, which are not suitable for insurance needs. The harvest index remains an important parameter; a basic calibration and validation of the harvest index are required. Approaches can be developed to optimize the harvest index based on reported crop production statistics or based on historical CCEs.

2.2. AI Models (Machine Learning / Deep Learning)

Crop yield has high variability across space and time owing to variations in weather, edaphic, management factors, and genotypes. Spectral data of a crop is the integrated manifestation of the effect of all the above factors, and hence, satellite data has a significant role in regional crop yield assessment. Remote sensing based spectral data has been incorporated into different statistical, agro-meteorological, and simulation models for crop yield assessment. Each approach has its own limitations like statistical methods are location specific and parametric in nature while agro-meteorological and simulation models are highly data intensive. Therefore, Artificial Intelligence (AI) has gained importance in solving the non-linear relationships between variables. AI includes Machine Learning and Deep Learning models, such as the random forest (RF), support vector machine (SVM), and different variants of neural network models (NN). In recent years, AI models have gained momentum in crop yield estimation due to certain inherent advantages with these models. Satellite-derived vegetation indices, meteorological data, hydrological variables, and edaphic factors are being used in these models.

Any deep learning model requires a large volume and variety of datasets during the training process. Therefore, to achieve a stable and robust DNN model for yield prediction, a large volume of crop yield data at all yield ranges (low, medium, high) is required. **The data availability at lower and higher yield ranges is to be ensured to minimise inaccuracies in model predictions.** Critical issues in the operational use of AI models are feature selection, optimization of model parameters, consistency of results, the scale of model development, etc.

2.3. Crop simulation models

Crop growth models simulate the plant processes to estimate various bio-physical parameters and final crop yield. These models need intensive parameterization starting from genetic coefficients of crop variety under cultivation, crop sowing time, crop management practices – fertilizer applications, irrigation supplies, pest/disease occurrence, etc. These are highly reliable point-based or location-specific models due to the availability of input parameters in experimental plots.
Input data in the model includes daily max & min temperature, daily solar radiation, daily rainfall, soil data - depth wise texture, bulk density, pH, organic carbon, water holding capacity, etc., Start of the sowing and irrigation information can be derived

from satellite images and other management factors can be taken from the standard local practices.

Model calibration and validation approaches are required for each selected model for the selected crop. The simulation models are sensitive to the genetic coefficients of the crop. A proper varietal-based approximation of genetic coefficients is required at the disaggregated level before simulating the crop yield. The modelling approach often remains lumped in absence of spatial input parameters unless space-based inputs are assimilated or externally incorporated. **The insurance units or agro ecologies with highly varying biophysical conditions need careful consideration on using simulation models and their yield extrapolation.**

2.4. Ensemble models (Machine Learning/ Crop Simulation/ Semi-physical)

An ensemble approach to yield estimation involves combining the predictions of multiple models to make a final estimation. This can be done through various techniques such as model averaging, model voting, or more sophisticated methods such as stacking. One advantage of using an ensembled approach is that it can potentially improve the accuracy of the final prediction by reducing the variance of the individual models. This is because the individual models may make different errors, and by combining their predictions, the errors may cancel out to some extent. To use an ensembled approach for yield estimation, one has to train multiple models on the same dataset. Different types of models can be used such as decision trees, support vector machines, or neural networks, or we could use the same type of model with different hyper parameter settings. These models can be clubbed with mechanistic approaches too. There are several benefits of using an ensembled approach for yield estimation:

2.4.1. Increased accuracy: By combining the predictions of multiple models, the ensembled approach can often provide more accurate predictions than any single model. This is because the individual models may have different strengths and weaknesses, and the ensembled approach can take advantage of the strengths of each model while minimizing the impact of their weaknesses.

2.4.2. Reduced variance: Using an ensembled approach can also reduce the variance of the predictions, which can be especially useful when the individual models are prone to overfitting or have high variance in their predictions.

2.4.3 Improved generalization: An ensembled approach can also improve the generalization of the model, meaning it can make more accurate predictions on unseen data.

2.5 Parametric index of crop performance (Indirect approach)

An alternate measure of crop performance, called Crop Health Factor (CHF), using mainly remote sensing data can be developed, and used for crop loss assessment in combination with CCE-yield estimates.

CHF is a composite index of crop performance incorporating multiple physical and biophysical parameters related to crop health. It is a quantitative measure of crop health and its overall performance. The research findings establish that the rationale for adopting CHF are (a) objectively measured yield-proxy-index is a better choice than subjectivity-prone manual yield estimates to design crop insurance contracts, (b) currently satellite and weather datasets permit more objective assessment of crop health at moderate spatial and temporal scales, (c) composite indicators are effective to simplify the complex processes into easily understood simple comparisons. Index-based insurance schemes are superior from ease of operation and objectivity point of view to conventional indemnity-based schemes using measured losses challenged by human errors, advertant or inadvertant, and hence these schemes are widely recognized for their successful implementation.

3. Key considerations in YES-Tech implementation:

3.1 Model implementation for past years: It is mandatory to implement these models for the current and past years from 2017 onwards. This is to ensure consistency in the model performance and outputs.

3.2 Recommended end use of model outputs: Blending of modelled crop yields or CHF with CCE-yield estimates is suggested for arriving at crop loss and claim assessments from the 2023 crop season. The weightage to be assigned to these two components is given below:

3.2.1 Direct yield estimation: 70% weightage to CCE yield and 30% weightage to modelled yield

3.2.2 Indirect approach (CHF model): 70% weightage to CCE-yield deviation from the threshold and 30% weightage to CHF deviation from the threshold.

The blending approach would lead to improving the loss assessment mechanism under PMFBY. **It reduces the dependence on the estimates of manual CCE**

systems. The scientific basis for assigning 30% weightage to technology can be drawn from the facts; (a) to result in a **meaningful impact on the final loss assessment**, (b) the benefit of technology adoption can be possible only when the **minimum possible and significant weightage** is assigned to the outcome. It is to be noted that the purpose of adopting models is to improve the yield estimation for loss assessment in the current year. The modelled outputs are not meant for changing AY and TY values.

3.3 Choice of models by states: Selection of model is at the discretion of States. It is mandatory to declare the selected model in the beginning of crop season in order to maintain transparency in the system.

3.4 Financial implications of model implementation: Implementation of any model proposed under YES-Tech involves cost considerations for field data collection for crop mapping, model training, and validation, computational facilities, data analysis, expert knowledge, etc. Moderate-resolution satellite data available in the public domain (10-30m granularity) will be used. The total cost of the project works out to Rs. 12-20 Lakhs per district per season approximately. This cost does not include UAV data acquisition and analysis because UAV technology is not mandatory in yield estimation models.

3.5 Implementation of YES-TECH

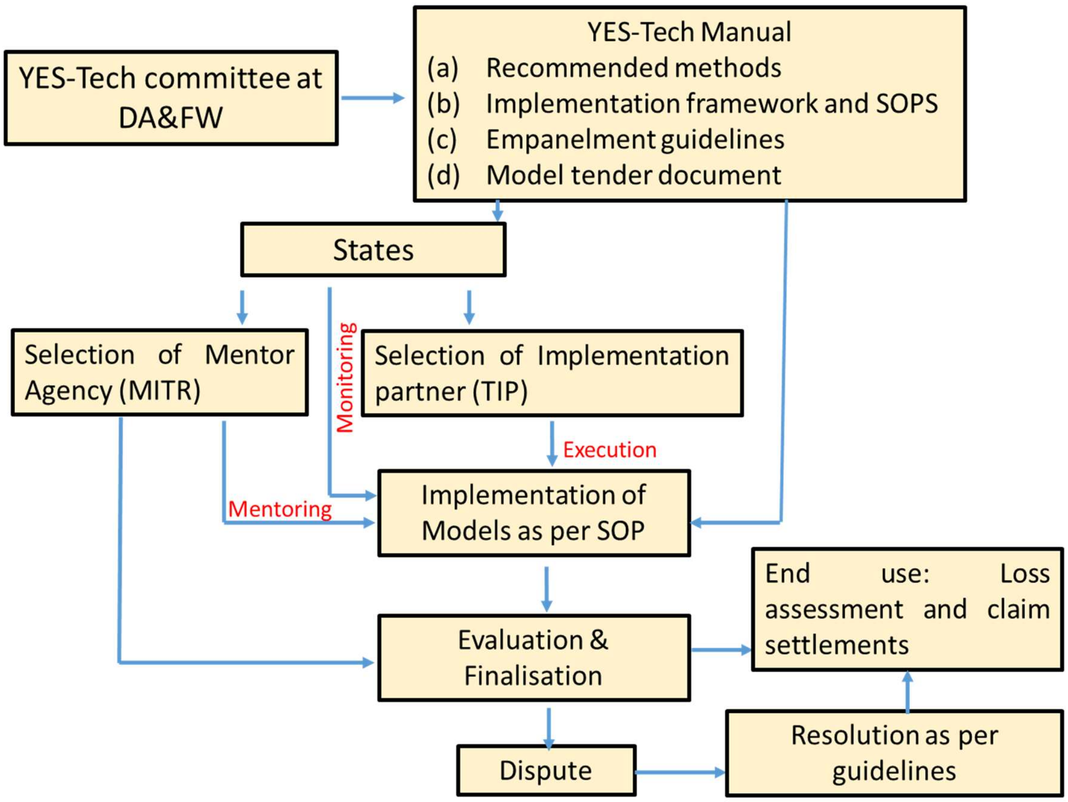
The framework for the implementation of YES-Tech models is depicted in Figure….. With the support of the current manual, states should select an **implementing agency** called **"Technology Implementation Partner (TIP)"** and a **mentor agency** called **"Mentoring Institute for Technology and Review (MITR)"**. TIP is selected through an empanelment procedure for which guidelines are furnished here for immediate reference. Potential MITR organizations are also provided in this document. MITR mentors, monitor implementation, and evaluate the results of models. That means MITR is associated with the total process end to end.

Standard Operating Procedures (SOP) for models detailing input parameters, source of input datasets to derive input parameters, training and validation data, etc. are described. These are broad guidelines that are subject to customization and fine-tuning.

States implement the selected model for yield estimation through TIP with the mentorship of MITR following the guidelines furnished in the SOP section of this document.

Thus, states are expected to implement the model of their choice through TIP with the support of MITR.

Fig1: YES-Tech implementation framework



3.5.1 Governing Body

There will be multiple agencies, working in different states for the targeted approach. The agency/agencies working in a particular state will report to the respective State Agriculture Department (SAD) which will be the sole governing body for monitoring the progress of the task.

3.5.2 Progress of the Implementation

The timely monitoring of the project will be done by the **SAD on fortnightly basis** and the implementing agency (tip)must submit a brief progress presentation to the respective SAD based on the data collection, ground truthing, crop monitoring, and identification in the study area, etc. The Tip will be following a broad structure for the work scope as set by the committee described below:

3.5.3 Mid-Term Report

The TIP will prepare a mid-term report on time and the contents of the report must include all the details.

- Description of the study area
- Data collected from state government (ancillary/current data)
- Data used for the Study including weather, Soil, Ground, Satellite, or any other data.
- Ground data collection status, including results of target crop classification and acreage estimation with help of mobile applications and Remote Sensing data analysis (both Space RS and/or UAV-sourced data)
- Crop health monitoring status via Space Remote sensing and UAV footage data processing (indices like NDVI, VCI, LSWI, Soil Moisture condition, etc.) as per established methodology with interpretations. The NDVI profile of the study area should be presented along with the NDVI deviation between the current and last normal year of that state. Other Indices should also be compared with their normal year values
- The current year's weather should be compared with the normal year of the study area and deviations should be interpreted

3.5.4 Final Yield Estimation Report

The TIP agency should submit the final report with the below-mentioned deliverables.

- Description of field data (summary tables with statistical analysis and any interpretation)
- Crop Area Estimations (statistics, maps, and accuracy)
- CCE data analysis and description
- GP level Yield estimates for current and past years from 2017 onwards, its comparison, and evaluation based on set statistical parameters
- Interpretation and discussion for GP level yield estimates, explaining the variance and losses if any
- Limitations and conclusions of the approach used for the study hurdles faced by the agency during implementation phase etc.

3.5.5 Mode of Delivery

YES-Tech reports will be submitted both through web interfaces at respective software platforms in printable format and as a separate electronic document report containing derived tabular and graphic crop yield data at the Insurance Unit level (Gram Panchayat). Reports will also be made available both to the assigned mentoring Agencies and authorized officers in Union MoAFW.

3.5.6 Web Monitoring Portal

The entire activity will have a web portal/dashboard rendering possibility for smooth monitoring of the progress of the work performance and deliverables by the TIPs.

3.6 Roles & responsibilities of stakeholders:

3.6.1 States / UT

a. State / UT shall consult Mahalanobis National Crop Forecast Centre (MNCFC) and understand the approaches recommended
b. State / UT may consult MNCFC, for information on potential agencies to act as TIPs.
c. State / UT shall refer to the model tender and in case required, they shall add additional scope that they wish to incorporate with the existing services.
d. State / UT shall get approval from MNCFC for scope of services finalized
e. State / UT shall adhere to the payment terms mentioned in the model tender document
f. State / UT shall decide the timeline of data/report submission based on their regional sowing pattern within 30 days of harvesting of the crop in the districts.
g. State / UT will give minimum weightage of 30% to the technology-based yield estimation and may decide higher weightage as well. The season-wise, and crop-wise weightage bifurcation should be sent to MNCFC for approval and the approved weightage should be part of the model tender
h. State / UT shall select a MITR organization from the list provided in the SOP for their respective states. MITR organization selection shall be done from the provided list only and it shall be clearly mentioned in the tender floated by the state
i. A letter of selection shall be sent to a MITR organization and States / UT must receive the confirmation before a tender is floated
j. State / UT shall adhere to the timeline specified in the SOP and the tender will be floated accordingly. The entire procedure shall be completed before the start of crop season
k. The state will mention the tender duration which should be between 3 to 5 years with a suitable exit clause.
l. State / UT will have the right either to allocate the work to a single agency or between maximum 2 agencies
m. State / UT will update MNCFC about the selected agency, the final rate, and the selected MITR organization
n. State / UT will provide the latest administrative boundaries, historical yield, or crop data to the selected agencies
o. State / UT will issue necessary authorization letters to the selected agency
p. State / UT will ensure a smooth field data collection activity, and drone survey activity, and necessary support will be provided to the selected agency
q. Once the reports/data are submitted, State / UT will conduct a review meeting where the selected agency, MITR organization, and relevant officials of DAFW will participate
r. State / UT will evaluate the result along with MITR organization and if the results are satisfactory then payment will be released as per -pre-determined payment terms.
s. If the selected agency has not delivered the results or the State / UT is not satisfied with the deliverable/methodology then initially State / UT will notify

the selected agency to correct the results. In case the results are not improved then the state / UT will escalate the matter to MNCFC for their intervention

t. If a satisfactory resolution is not received even after MNCFC's intervention then State / UT will have a right to raise the obligation and proceed for the exit with the selected agency

v. State / UT will share the collected data (field data, CCE data, drone data, etc.) under the project with MNCFC

w. State / UT will organize capacity-building training/workshops for the Govt. officials and other stakeholders

x. State / UT will share the CCE data collected by them with TIP for their model validation within 30 days of CCEs.

3.6.2 Mahalanobis National Crop Forecast Centre (MNCFC)

a. MNCFC will support and coordinate with State / UT for implementing YES-TECH

b. MNCFC will apprise State / UT and other relevant stakeholders about the approved methodologies for the technology-based yield estimation, the agencies which are empanelled, SOP, model tender, etc.

c. MNCFC to coordinate with potential MITR organizations for their role in the scheme implementation

d. MNCFC will provide a list of MITR Organizations that will provide technical expertise to the State / UT in the project

e. If the State / UT has altered the scope of services mentioned in the model tender then the finalized scope of services should be sent to MNCFC for approval. MNCFC may also inform State / UT to have a new separate tender if the modified scope of services is not aligned with the existing scope of services mentioned in the model tender

f. MNCFC will decide the timeline of milestone delivery and frequency of deliverables as per the State / UT's need

g. MNCFC will help deciding the payment terms in the model tender if the States are in need of it.

h. MNCFC will monitor the agency selection procedure of various States / UT

i. MNCFC will help State in the cost justification if needed during the agency selection procedure.

j. MNCFC will develop a procedure to regularly pull the necessary data such as field data, and CCE data from the respective agencies and store it in the central repository.

k. MNCFC will support the MITR organization in methodology evaluation

l. MNCFC will serve as a Technical Advisory Committee (TAC) and will have the necessary infrastructure and expertise to guide the State / UT or MITR organizations.

m. MNCFC will act as an orchestrator for all projects related activities and a single point of contact (SPOC) to MOAFW India, PMFBY management.

3.6.3 MITR Organization

a. MITR organization will inform MNCFC about their association with multiple States / UT in the scheme implementation
b. MITR organization will serve as a **State Advisory Committee (SAC)** and will ensure the necessary infrastructure and expertise
c. MITR organization will understand the methodology to be implemented, expectations in the milestone delivery from the State / UT
d. MITR organization will understand the overall approach of delivery, inputs to be used from the selected agency
e. MITR organization will identify a Single Point of Contact (SPOC) for each state
f. MITR organization will participate in the review meetings as per the State / UT's predefined timeline
g. MITR organization will evaluate the methodology and produce results technically and approve/reject the results
h. MITR organization will provide technical guidance to the selected agency if the results are rejected and MITR organization will also ensure the improvement in the deliverables to the State / UT

3.6.4 Technology Implementation Partner (TIP)

a. TIP will participate in the closed bid floated by the respective State / UT
b. TIP will consult with the State / UT for the area distribution if more than one agency is selected by State / UT
c. TIP will request administrative boundary, historical yield/crop data from the State /UT
d. TIP will conduct a kick-off meeting with State / UT representative, MITR organization, and other relevant stakeholders where TIP will briefly explain the selected methodology, planning for the milestone deliverables, inputs required, required authorization letters from the State, etc.
e. TIP will consult State / UT for the necessary approvals related to the field activities such as field data collection, drone survey, CCE sample collection, etc.
f. TIP will submit the results as per the defined timeline and it will participate in the review meeting with the State, MITR Organization, and other stakeholders at a regular interval
g. TIP will consult the MITR organization / State if the results are not satisfactory and TIP will submit a plan to improve it
h. TIP will hand over the data collected from the field at the end of the project
i. TIP will push the results to MNCFC where MNCFC will store them in the central repository

3.7 Selection Procedure for engaging TIP agency

State / UT will follow the following procedure to on board a TIP for the technology-based yield estimation project.

a. A State / UT will first understand the methodologies notified under YES-TECH.
b. MNCFC will provide an SOP, a list of empanelled agencies, and a model tender to the state

c. An SOP will consist of the description of methodologies selected, entry and exit criteria, legal standpoint, roles & responsibilities of various stakeholders
d. The empanelled list will consist of companies' name and their methodology description
e. The model tender will consist of a basic scope of work, payment terms, milestone delivery timelines, a list of MITR organizations, etc.
f. The model tender will have the basic scope of work such as Crop acreage estimation at the Gram Panchayat level / Insurance Unit level, crop health monitoring, cereal crops yield estimation at the IU level, a mobile application for the field data collection, a web-based platform for the data hosting and for a decision making
g. A State / UT will decide the project duration. The project duration will be of minimum 3 years
h. A State / UT may go through the model tender document and they will have a provision to add the additional scope of services. However, the additional scope of services shall be approved by MNCFC before the tender is floated
i. MNCFC may approve or reject the additional scope of service and it will be a State / UT's decision whether to have a new tender for the additional scope of services that are rejected by MNCFC
j. A State / UT will also get updates about the funding. State / UT has to approve the budget and should get clarity about which scheme the budget will be approved for.
k. Once necessary approvals are received, a State / UT will float the closed tender to the empanelled agencies only
l. The empanelled agencies will participate in the bid and therefore no separate technical bid is required and the TIPs will submit their commercial proposal only.
m. The State / UT will validate the necessary document before opening the financial proposal
n. Once the bid is opened, the State / UT may contact MNCFC for the cost justification if required
o. A State / UT may give the entire work to a single TIP or if multiple TIP wish to do the work on the L1 rate then State / UT shall divide the work among 2 TIP
p. Maximum TIP allotted for the work should not be more than 2
q. The State / UT will evenly distribute the area if 2 TIPs are selected
r. Once the process is over, a State / UT will issue a Letter of Intent (LOI) to the selected agencies followed by the agreement and the same shall be informed to MNCFC.

3.8 Rate contract mechanism with a price band

In order to ensure that the implementation of the technology is done in the most efficient manner, we are proposing the rate contract methodology be deployed. Rate contract is established for Single / multi Picking, majority acreage / minor acreage (provision to buy High-resolution imagery), calamity situation (with provision for drone usage and field surveys) with contract rates and reimbursable defined clearly. Rate Contract System with Price band and work distribution mechanism to be introduced on Central Government Level to establish the pricing of technically qualified agencies for major ongoing seasonal activities related to:

- Acreage estimation
- Crop health monitoring
- Implementation of smart sampling CCEs
- Technology based yield estimation

The essence of the contract is to carry out maximum activities as per the scope of Rate Contract in line with the requirement established by MNCFC and also shall capture the performance of agencies during the execution of contract

The advantages of rate contract are as follows:

A. The main purpose of proposing a rate-card based contract is to ensure timely activities each season.
B. There should be a process of rate revision every 3 years, the process must start after 2 years and MNCFC will publish the revised guide-rates at the start of Kharif '26 (rates will be published by December 25). Rediscovery of rates each season will cause delays due to bureaucratic formalities.
C. Since the rate contract includes all the necessary/ required tools for technology implementation, the deployment would be standardized
D. Price discovery will be done only once, thereby reducing the time and effort at each state level
E. Standardized scope of work and a fair evaluation process
F. This rate card should be valid from Kharif '23 up to Rabi '26

The rate contract would have the provision of establishing rates for all different facets of technology deployment for example: Single picking/ multi picking, long/ short duration, size of district, major crop/ minor crop amongst others.

The commercials will be segregated based on fixed costs and reimbursable. Types of fixed costs are: Cost of field surveys (GCPs & CCEs), Manpower costs, analysis costs. Types of reimbursable are: Cost of satellites, drones/ UAVs, weather stations and other types of data.

3.9 Legal Standing of the Deliverable provided by the TIPs

Monitoring Mechanism: Monitoring of the TIPs agencies will be carried out by the MITR organization identified by the MNCFC/State authorities. The Role of the MITR organization will be limited to providing technical inputs and review.

A- of the technical work done by the TIP agencies. MITR organization will not interfere in any field and operational activities of the TIP agencies.

B- Necessary Approvals: The State/UT will help/provide all necessary approvals from the relevant authorities of the state/central to carry out the field activities such as drone flying/GT/CHM/CCE or any other requirement.

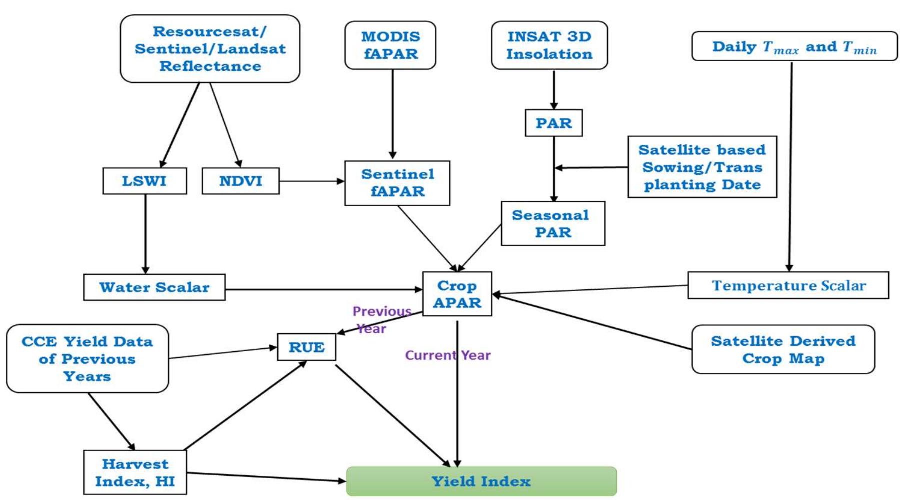
C- Escalation Mechanism: In case of any escalation regarding the results of the Research, client will ask and provide sufficient time to the TIPs agencies to revisit the results and submit the revised results to client as per the agreed timelines.

4. STANDARD OPERATING PROCEDURE FOR IMPLEMENTING THE MODELS

4.1 Semi Physical Approach

The methodology is based on the concept that the biomass produced by a crop is a function of the amount of photo synthetically active radiation (PAR) absorbed, which in turn depends on incoming radiation and the crop's PAR interception capacity. Biomass is a function of the total photo synthetically active radiation (PAR) and the ability of the plant to absorb (fAPAR) this radiation and to convert this radiation to dry matter (RUE) and yield is a function of net dry matter and the harvest index (HI) of the crop. Water Scalar derived from satellite images will be used as a limiting factor of crop yield. Major factors of crop growth (i.e.) the radiation and the ability of the crop to convert the absorbed radiation into dry matter) are derived and used for estimating the yield. Model framework (flow chart) is furnished in Fig. below

Fig 2: Semi-physical model framework



PAR- Photosynthetically Active Radiation, APAR- Absorbed PAR by the crop, fAPAR – fraction of APAR, LSWI – Land Surface Water Index, NDVI – Normalized Difference Vegetation Index, RUE – Radiation Use Efficiency, CCE- Crop Cutting Experiments

4.1.1 Methodology

The generation of an accurate crop map for the current and historical years is the first important step in all the five approaches. Crop layers can be generated using SAR and Optical medium resolution (5-30 m) satellite data. The standard widely adopted methodology must be followed for crop mapping.

The classification procedure has to be performed for each district separately, and the outputs are to be verified extensively by superimposing on cloud-free optical data of appropriate months when the crop was at maximum vegetative phase. Field data points are used to check the classification performance. It is to be ensured that commission errors are <10% and omission errors can be accommodated up to 20%. By adopting this strategy on mapping error, **the IU average crop health indicators** represent the crop pixels more closely.

4.1.2 Input data

Basic Input Data for Model development are Fraction of absorbed photo synthetically active radiation (fAPAR), Photo synthetically active radiation (PAR), Radiation use efficiency (RUE), Water scalar, and Harvest Index (HI) data will be used for yield estimation. Details of data product, satellite, Source, and Granularity is given in table below-

Table 1: Input data details of model

Data /Product	**Satellite/ Ground**	**Sensor**	**Resolution**	**Source**
Daily integrated Insolation	INSAT 3D	Imager	1 km	MOSDAC
8-days composite FAPAR	Terra Sentinel 3	MODIS OLCI	0.5 km 0.3 km	NASA-EARTHDATA ESA
8-days composite surface reflectance	Terra Sentinel 2	MODIS MSI	0.5 km 10-20m	NASA-EARTHDATA To be developed by TIP
NDVI & LSWI during Maximum Vegetative Stage	Sentinel 2 Landsat 8	MSI OLI	10-20 m 30 m	ESA NASA-EARTHDATA
Crop mask (5-30 meter) resolutions	Sentinel 1 Sentinel 2 Landsat 8	SAR MSI OLI	20 m 10 m 30 m	To be developed by TIP
Crop Sowing Date	Sentinel 1 Sentinel 2 Landsat 8	SAR MSI OLI	20 m 10 m 30 m	To be developed by TIP
Harvest Index	Ground Data CCE	---	District Level	CCEsconducted by TIP
Daily Tmin and Tmax	Gridded Data	---	0.5o x 0.5o 5 km Grid	IMD Pune Website WRF short-range forecast of SAC

4.1.3 Derivatives/metric generation

The model of accumulation of biomass for paddy crop can be written in a general form as:

NPP/Biomass=RUE*fAPAR*PAR*Wscalar* Temp Stress

where NPP is the Net Primary Productivity/Bio mass accumulated during the day; RUE is the radiation/light use efficiency of the plant; FAPAR is the fraction of radiation absorbed by the vegetation cover; PAR is photo synthetically active radiation.

NPP = Net Primary Productivity or dry matter accumulation in plant over a period of time ($gm^{-2}d^{-1}$); PAR = photo synthetically active radiation ($MJm^{-2}d^{-1}$); fAPAR= fraction of incident PAR which is intercepted and absorbed by the canopy (dimensionless); RUE = Light-use efficiency of absorbed photo synthetically active radiation (gMJ^{-1})

Biomass and Yield Estimation: Harvest Index (HI) will be calculated from CCE collected points. The biomass and the yield had been calculated from the given formula-

Yield=Biomass*HI

4.1.4 Validation

Validation activities could be carried out for past years' yield data. Good quality CCE estimates as guided by State Government at the Insurance Unit level could be used for this purpose

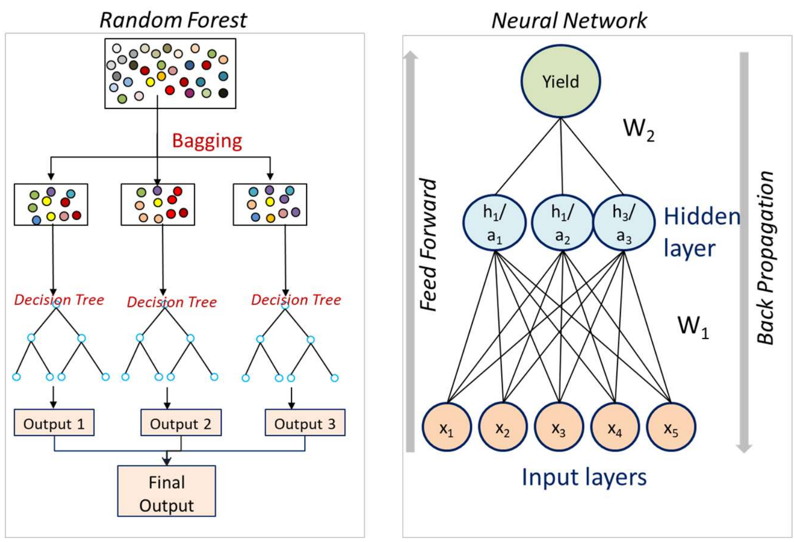
Modelled yield estimates need to be generated for the current and at least the past years (2017 onwards) at the insurance unit level for a given crop.

4.2 Machine Learning / Deep Learning approach

Machine learning is a component of artificial intelligence that provides a computer the ability to learn from data without being explicitly programmed for it. Machine learning models are non-parametric and captures the non-linear relationships between the yield and the features influencing the yield. Machine learning can determine pattern and correlations and develop the predictive model. The predictive model is built using several features, and as such, parameters of the models are determined using historical data during the training phase. In recent years, machine learning models have been used in various researches to improve the accuracy of crop yield by incorporating satellite derived vegetation indices, meteorological data, hydrological variables, edaphic factors etc.

Two machine learning approaches are mostly followed in the literatures i.e., Decision tree based like random forest and Deep neural network based. Random forest (RF) is a supervised ensemble learning model which combines the output of multiple decision trees to make the final prediction. Each decision tree is trained in isolation and grown in random subspaces of data by using Classification and Decision Tree (CART) methodology. Deep Neural Networks (DNN) utilizes the principle of universal approximation theorem which states that a fully connected feed forward neural network with finite number of layers and neurons can approximate any kind of relationship between input and the output variables (Fig.).

Fig 3: Schematic flowchart representing Machine learning models



4.2.1 Workflow

Machine learning workflow consists of pre-processing, feature design, splitting data into training and validation sets, selecting machine learning algorithm, training, optimization, evaluations and testing. Datasets from various sources, satellite derived, weather, soil and yield need to be homogenized and aligned to the same spatial and temporal resolutions. Training, validation and testing datasets need to be mutually explicit.

4.2.2 Datasets

Crop yield is the result of a complex interaction between weather, edaphic, management factors and genotypes. Datasets/features must represent these factors and should have physical meaning in terms of their impact on crop growth and development. Spectral data over the crop is the integrated manifestation of the effect of all the above factors and hence, satellite data can be used as feature in the Machine learning models. Table represents various datasets commonly used in the machine learning models.

Table 2: Commonly used datasets for ML based crop yield estimation

Category	Features	Source
Satellite based	Reflectance bands	Sentinel-2, Landsat-8, MODIS
	Vegetation Indices-Greenness (NDVI, EVI, Red edge index)	Sentinel-2, Landsat-8, MODIS
	Vegetation Indices-wetness (NDWI, LSWI, etc)	Sentinel-2, Landsat-8, MODIS
	Radar backscatter (VH, VV, RVI etc)	Sentinel-1, EOS-4
Meteorological	Rainfall, Rainy Days	IMD gridded, CHIRPS, any other gridded/reanalysis data
	Dry-spell/Wet-spell	IMD gridded, CHIRPS, any other gridded/reanalysis data
	Temperature	IMD gridded, any other gridded/reanalysis data
	Growing degree days	IMD gridded, CHIRPS, any other gridded/reanalysis data
	Heat wave/cold wave	IMD gridded, CHIRPS, any other gridded/reanalysis data
Bio-physical	FAPAR	PROVA/Sentinel-3, MODIS, Sentinel-2
	LAI	PROVA/Sentinel-3, MODIS, Sentinel-2
Edaphic	Soil (texture, depth, AWC, etc)	NBSSLUP (1: 250K, 1:50K)
	DEM	SRTM, DEM
	Soil moisture	SMAP, AMSR-E

4.2.3 Feature Selection, training and optimization

Feature selection should be performed such that each feature should provide unique information about crop growth. Crop growing period (start of the season, end of the season) should be considered for selecting the features. Multivariate analysis needs to be performed to check the multi-collinearity between the features. Appropriate data normalization technique needs to follow for bringing datasets to same unit. Gap-filling and outlier removal should be done through standard statistical procedure.

Regularization criteria must be followed to check the overfitting of the model. Optimization function should be reflected as an output to visualize the learning rate, batch size etc. Feature importance should be computed to check the weightage to each feature. Statistical criteria need to be considered for accuracy, such as the mathematical expectation of mean absolute of forecast error MAE, RMSE or NRMSE.

In case of Neural network model, the following parameters need to be explicitly mentioned by the agency

- Network Architecture
- Activation function
- Learning Algorithm
- Learning rate
- Loss Function
- Regularization criteria
- Number of training epochs
- Batch size

For decision tree based models the following configuration

- Number of trees
- No. of features randomly selected at each node
- Best feature selection criteria
- Minimum Leaf size

If any Feature engineering is adopted the its effect on the model performance need to be documented.

4.2.4 Model implementation & Deliverables

The validated model needs to be run for the current season and the final deliverables will be the modelled yield of insurance units for the current and historical (at least 5 years) years.

4.2.5 Training and Validation approach

For model training and validation, stratified random sampling approach from different yield classes need to be followed. From each yield class range at least 30% randomly selected dataset should be used for model validation and the rest for training.

A good quality training yield data (CCE/IU averaged) as vetted by the state agricultural department from historical crop season should be used.

4.3 Crop Simulation Model Approach

(This guideline applies whether CSM is applied as a standalone or by assimilating remote sensing data, see the section on crop assimilation data)

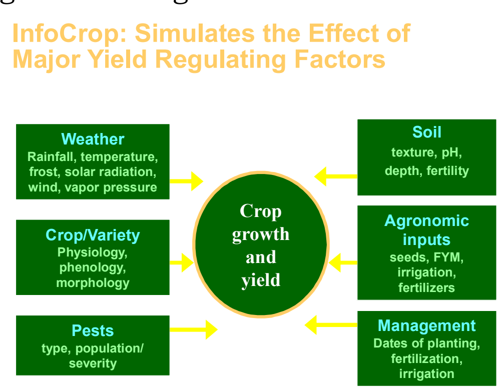
4.3.1 Brief Description: Crop growth models simulate the plant processes to estimate various bio-physical parameters and final crop yield. These models need intensive parameterization starting from genetic coefficients of crop variety under cultivation, crop sowing time, crop management practices – fertilizer applications, irrigation supplies, pest/disease occurrence, etc., These are highly reliable point-based or location-specific models due to the availability of input parameters in experimental plots. Calibrated and validated crop simulation models (DSSAT, APSIM, InfoCrop, etc.,) for Indian conditions together with soils and cultivar data available locally from SAUs and NBSSLUP. These models are well-calibrated and validated for several crops such as wheat, rice, maize, sorghum, potato, soybean, chickpea, mustard, groundnut, cotton, and coconut in Indian agroecological conditions. The following processes are considered in most of these models:

- Crop growth and development: phenology, photosynthesis, partitioning, leaf area growth, storage organ numbers, source: sink balance, transpiration, uptake, allocation, and redistribution of nitrogen.
- Effects of water, nitrogen, temperature, flooding, and frost stresses on crop growth and development.
- Soil water balance: root water uptake, inter-layer movement, drainage, evaporation, runoff, ponding.
- Soil nitrogen balance: mineralization, uptake, nitrification, volatilization, interlayer movement, denitrification, leaching.
- Soil organic carbon dynamics: mineralization and immobilization.

4.3.2 Model framework

The crop models are process-based dynamic simulation models for simulating the growth, development, and yield of crops. They simulate the effects of weather, soil, and crop management (sowing, seed rate, organic matter nitrogen, and irrigation), and pests (some models). It provides daily and summary outputs on various growth and yield parameters, nitrogen uptake, soil water, and nitrogen balance. Several researchers have shown the application and utility of crop simulation models in India. Below a sample modelling framework is shown for Info Crop.

Fig 4: Modelling framework for Info Crop



Input data in the model includes daily max & min temperature, daily Solar Radiation (IMD AWS), Daily Rainfall (IMD AWS), Soil data - Depth wise texture, BD, pH, Organic carbon, water holding capacity, etc. The crop management information such as sowing dates and irrigation information can be derived from satellite images and used to drive simulation, and other management factors are taken as per the standard local practices. The output from the CSMs is like yield, total dry matter, crop duration, evapotranspiration, N uptake, and soil C, N, and water dynamics.

4.3.3 Key considerations:

- There are several crop-simulation models available in the literature, however, they have varying accuracy, and only a few of them are tested thoroughly for Indian conditions. Emphasis should be given to the use of those models that have proven accuracy, and calibrated parameter values (e.g., cultivar coefficients) are available.
- The granularity of outputs derived from CSMs depends on the granularity of input datasets. To improve the granularity, spatial simulations should be done by considering variations in soil, weather, and other input parameters like sowing dates. Crop area-based aggregation must be applied to derive final yields at the IU level.
- Another approach to improving the granularity is to assimilate remote sensing data (e.g., LAI, soil moisture) in the crop simulation models. Remote sensing data assimilation and subsequent updating of the state variables in the CSM should be done using methodologies tested and published in peer-reviewed research journals.

4.3.4 Methodology

1.1 Crop Classification: See Annexure I.
1.2 Input data for the CSM approach and CSM-RS approach

* Crop models distinguish varieties of a crop by their differences in phenology, growth, and source-sink balance. In most cases, thermal times of three phenological phases, the sensitivity to photoperiod, early vigor (defined in the model as relative LAI growth rate during initial stages), index of storage organs formation (slope of the relation between SO and growth during SO formation stage), and the potential weight of the storage organs were sufficient to adequately characterize the varieties.

Table 3 Input data required for CSM approach and CSM-RS approach

Sr. No.	Work Component	Description and costs	Source
1	Weather data	• IMD daily weather data (station) for the current season and historical (more than 7 years) • Real-time and historical satellite/gridded weather data (daily) • Minimum weather data: Daily rainfall, temperature (maximum and minimum) • Additional weather data: Solar radiation, wind speed, humidity	IMD, ERA5, CPC/CHIRPS or any other gridded/reanalysis /satellite-derived data
2	Soil Data	• Soil physical properties by layers: Bulk density, soil texture, depth • Soil chemical properties by layers: Organic carbon, EC, pH	NBSSLUP Soil Health Card Gridded soil data (SoilGrids) Field survey
3	Crop Management data	• Agronomic data on fertilizer, seed rate, crop duration, irrigated area, rained area, cultivars, sowing depth, etc., • Sowing dates	From various Govt Dept., Field surveys & Information from KVKs Using the above inputs and RS data (Sentinel 1, 2, and Landsat 8)
4	Crop model-specific data*	• Crop coefficients • Phenology	Literature
5	Remote sensing data (for assimilation)	• LAI • Soil moisture	MODIS (250/500 m), Sentinel product

4.3.5 Calibration and Validation

Model calibration and validation approaches are required for each selected model for the selected crop. The simulation models are sensitive to the genetic coefficients of the crop cultivar. A proper varietal-based approximation of genetic coefficients is required at disaggregated levels before simulating the crop yield. The calibration process should be done with care, and it should be ensured that the parameters do not exceed the biological range. The datasets from KVK, SAUs, or ICAR institutes should be used to check the quality of the simulation.

4.3.6 Deliverables

The final deliverable will be a model yield estimate for the current and at least the past five years for the given crop at the IU level. The error (nRMSE) between the observed and modeled yield should not be more than 30% in historical data. All IUs where the error is more than 30% should not use this methodology.

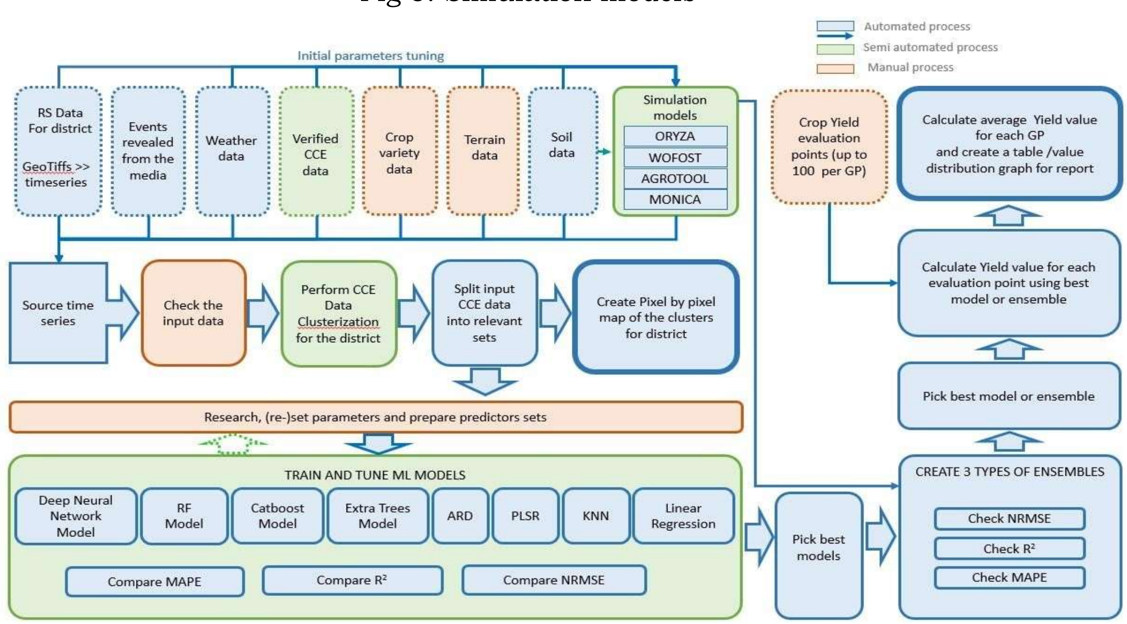
4.4 Ensemble models (Machine Learning/ Crop Simulation/ Semi-physical)

4.4.1 Brief description

An ensembled approach to yield estimation involves combining the predictions of multiple models to make a final prediction. This can be done through various techniques such as model averaging, model voting, or more sophisticated methods such as stacking. One advantage of using an ensembled approach is that it can improve the accuracy of the yield estimation by reducing the variance of the predictions. This is because the individual models may make different errors, and by combining their predictions, the errors can cancel out to some extent. An ensembled approach can also improve the robustness of the yield estimation, as it can be less sensitive to the specific choice of model or training data used.

In this approach, input obtained from Simulation and Machine learning approaches will be combined through scientifically designed techniques. Most accurate results are obtained by ensembling methods (weighted average, stacking). The Machine Learning approach would be Linear regression, Random Forest, ExtraTrees, gradient boosting (CatBoost), neural networks (Pytorch Tabnet), k-nearest neighbors. Simulation models (e.g. ORYZA, WOFOST, Infocrop, DSSAT, APSIM) are used, along with data assimilation technology. Brief flow diagram of approach may be as follows-

Fig 5. Simulation models



4.4.2 Methodology

There are several different methods for ensembling models, including bagging, boosting, and stacking. It is important to choose the appropriate ensembling method based on the specific characteristics of the data and the goals of the modeling process. Basic input data requirement is as given below-

4.4.3 Input data

a) Satellite data-

- **Preferably** Sentinel 1A/B (IW mode, VV and VH polarizations,10m resolutions
- Sentinel 2A/B (multispectral 12 bands, 10m resolutions
- Landsat 8-9 (multispectral 12 bands, 20m resolutions
- MODIS Terra/Aqua: (VI's 8- and 16-Day Composites, Daily Cloud Mask 250m)

b) **Weather data** – IMD, ERA5, CPS, CHIRPS or any other gridded or satellite derived data

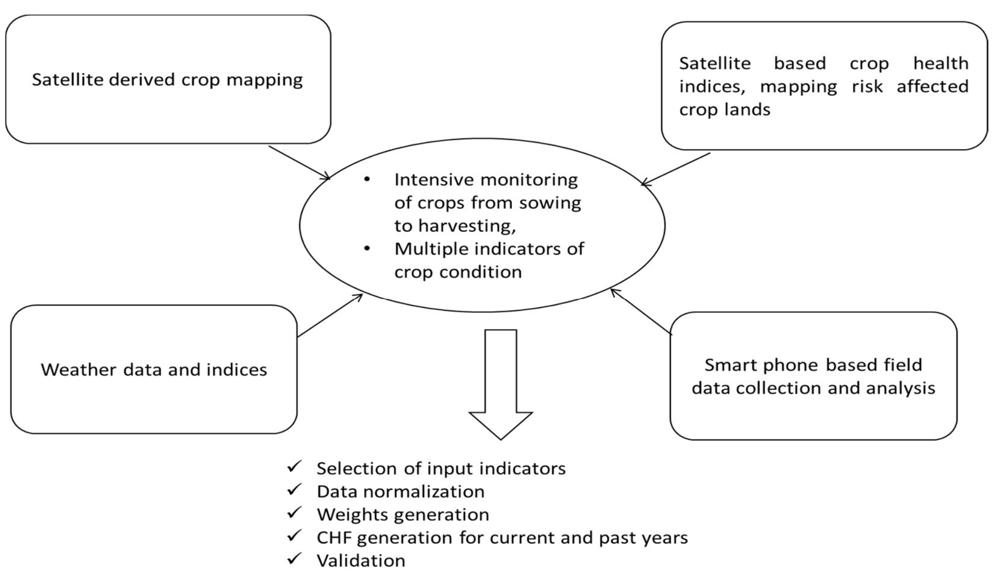
c) **Soil data-** NBSSLUP or Soil Grids Model Data at different depth intervals

d) **Ground based observations**- CCE and GT observations for management observations

4.5 Parametric index of crop performance (Indirect approach)

The framework of computation of crop performance index (CHF) is presented in Fig 1. Satellite-based crop mapping, satellite and weather data analysis for generating crop health indicators, field data collection and analysis, composite index generation, and insurance loss assessment are significant tasks in this framework.

Fig 6. CHF generation framework



4.5.1 Methodology

Field data collection

A robust system of mobile-based crop surveillance is part of this approach for close and continuous monitoring of the agricultural situation. Protocols includes two types of field datasets i.e., reference and random. Reference points were observed multiple times to monitor crop performance, whereas random points were covered at least once in a season. It should be ensured that every block (a group of GPs) was represented by at least 10-20 GT points, and 1-2 GT points represent each GP within the block at each time of data collection. Thus, an extensive repository of field data points is the requirement in the analysis to show substantive evidence on the ground situation. These field data points were linked to satellite indices for crop classification and crop condition assessment.

4.5.2 Crop mapping

Refer the methodology section of Semi-physical approach

4.5.3 Basic indices data

The following set of indices derived from satellite and weather datasets that are well reported to be related to crop condition were part of a vast repository of data in the current project.

- **Satellite derived**
  - Normalized Difference Vegetation Index (NDVI)
  - Land Surface Wetness Index (LSWI)
  - RADAR backscatter
  - Fraction of Photosynthetic Active Radiation (FAPAR)/Leaf area index (LAI)

- **Weather data**
  - season's rainfall
  - rainy days
  - temperature,
  - wind speed
  - humidity

Major input datasets and their details mentioned in the Tables under Machine learning approach and crop simulation approach are also relevant for CHF generation

4.5.4 CHF generation

The important elements of the CHF generation procedure include the selection of input variables, data matrix preparation for all the IUs and years, grouping of IUs in each district, data normalization, weights generation, and index development followed by its validation.

Fortnightly and monthly time composite NDVI and LSWI images and 12-day interval SAR VH backscatter images are to be generated covering entire crop season for the current and past years. Crop layer and shapefile of IUs are used to create the data of sub-indicators. Input parameters of the model along with their functional relationship with CHF for paddy crop are shown in Table given below.

From the NDVI profile of each year, the maximum NDVI value occurring at n^{th} fortnight and the NDVI of either $n+1^{th}$ or $n-1^{th}$ fortnight, whichever is higher, were averaged. Averaging two values of NDVI reduces uncertainty and ensures a better representation of the season's maximum value. A similar approach was adopted for computing the season's maximum LSWI and Backscatter. Integrated VH backscatter represents the total Backscatter of all the data of the growing season. Integrated FAPAR (sowing to harvesting) – Monthly composite FAPAR data from September to the first fortnight of November, when the crop is actively growing and maximum vegetative phase are summed up. Crop condition variability was represented by the maximum of the Coefficient of Variation (CV) values of NDVI and LSWI) CV was computed using mean and standard deviation of respective index in a given IU.

Table 4: Input parameters of the CHF model for paddy (illustrative example)

S.No.	Input indicator	Functional relationship with CHF
1	Seasons' maximum NDVI	Positive
2	Season's maximum LSWI	Positive
3	Season's maximum VH backscatter	Positive
4	Integrated VH backscatter	Positive
5	Integrated FAPAR	Positive
6	Crop condition variability	Negative
7	Rainfall	Positive
8	Rainy days	Positive

Justification for the above parameters is drawn from the reported research. Season's maximum NDVI and LSWI, included in the model, were reported to be effective in crop condition assessment and crop yield modelling by many studies. SAR backscatter data was used to infer the LAI values of rice crop and used them as relative leaf growth rate parameters in the ORYZA model. Time series data of $\sigma 0$ offers reliable information about the crop growth stage, such as jointing and heading in grain crops and leaf development and reproduction. FAPAR integral over the season is one of the indicators of biomass production from vegetation. FAPAR integral used to design index-based insurance over grasslands. FAPAR was successfully used in grain yield estimation procedures. Rainfall and rainy days are vital determinants in crop production in India.

Rainfall quantity shows differential effects on crop performance. Increase in rainfall up to certain level benefits the crop and beyond certain quantity of increase it harms the crop. In this project, we have included only benefit-causing limit of rainfall, which was fixed at 150% of normal rainfall. India Meteorological Department defines normal rainfall limit as 80-120% of long-term average (www.imd.gov.in). We have considered an additional quantity of 30% assuming that it benefits the water loving paddy crop, and thus fixed the upper limit of rainfall quantity corresponding to 150% of long-term average. It is assumed that the negative effects of excess rainfall quantity beyond 150% limit, on crop performance would be captured by other parameters, i.e., NDVI, LSWI, and Backscatter. The impact of deficit rainfall on crop would anywhere be reflected in these spectral indices.

4.5.4.1 Stratification of the IUs

The IUs of each district are first segregated into homogeneous groups based on NDVI, rainfall, and soil water holding capacity datasets. It is to be ensured that each group consists of at least 4 IUs that are contiguously located. By pooling contiguous IUs into a group, the number of crop scenarios would be increased. For example, a group with four IUs and four crop years (2016 to 2019) has 16 crop growing scenarios, adequate to capture the variability. The dynamic ranges of input indicators of the CHF model are more or less the same in each group because it represents a homogeneous crop growing environment. On the other hand, if each IU is treated as a discrete / standalone entity, there are only four crop growing scenarios, and such a limited database cannot represent the total variability of crop responses leading to biased weights. All the steps in CHF computation – data normalization, weights generation, and applying weights for final index generation are carried out in each stratum independently.

4.5.4.2 Data normalization

The data is first checked for redundancy by comparing the inter-correlations between the variables. The input indicators of the model were in different units. Their functional relationships with CHF is either positive or negative as mentioned in the Table above. To obtain these indicators unit-free, data normalization was done by following the widely recommended Min-Max approach.

In the case of the input-indicators that have a positive relationship with CHF, normalization was done using the formula;

$$x_{ij} = \frac{X_{ij}\text{-}Min\{X_{ij}\}}{Max\{X_{ij}\}_i - Min\{X_{ij}\}}$$

In the case of the input-indicators having a negative relationship with CHF, normalization was done using the formula;

$$x_{ij} = \frac{Max\{X_{ij}\}\text{-}X_{ij}}{Max\{X_{ij}\}_i - Min\{X_{ij}\}}$$

4.5.4.3 Weights generation and CHF computation

After normalization, the input indicators were ranging from 0-1. Derivation of weights to input indicators is vital in constructing composite indices (Brooks et al. 2005). There are many methods of weight generation in a composite data framework (OECD 2008). Wilhelmi and Wilhite (2002) selected weights based on the relative contribution of each factor to their drought vulnerability study. Li et al. (2006) used Principal Component Analysis to generate weights for the variables. Brooks et al. (2005) assigned equal weights to each indicator in their study. Murthy et al. (2016) adopted the variance approach in their study on drought proneness.

Feature extraction techniques such as Principal Component Analysis, Partial Least Squares, multi-criteria decision models are also used to aggregate different variables into a single index. But linearity assumption in data transformation is a serious limitation in most feature extraction techniques (Rajasekhar et al. 2015). Entropy technique based on information theory depends on the disorder degree of information. It is a more effective information measure providing balanced relationships and unbiased weights better than linear methods (Waseem et al. 2015, Rajasekhar et al. 2015, Liu et al. 2019). The entropy-based weighting technique was adopted in this project, considering its merits. The entropy-derived variability of a feature and its weight are directly related. This technique does not include any assumptions, cumbersome derivations, and transformations.

Consider a normalized data matrix D which consists of *o*bservation for *f*eatures, where x_{ij} denotes the value of the j^{th} feature of i^{th} observation. The entropy of the j^{th} feature, E_j, can be calculated as:

$$E_j = -\frac{1}{\log(n)} \sum_{i=1}^{i=n} \frac{x_{ij}}{\sum_{i=1}^{n} x_{ij}} * \log\left(\frac{x_{ij}}{\sum_{i=1}^{n} x_{ij}}\right)$$

The weight of the feature can then be calculated as:

$$w_j = \frac{1 - E_j}{m - \sum_{j=1}^{m} E_j}$$

Given the weight (w's) and the normalized feature values of i^{th} IU. (x_{ij}'s), the Crop Health Factor (CHF) can be calculated as:

$$CHF_I = \sum_{j=1}^{m} w_j * x_{ij}$$

4.5.4.4 Data and outputs

Representative values of CHF for different IUs are furnished in Table 5 for illustration purpoae.

Table 5: CHF values of different Insurance Units (illustrative example)

Block _code	GP_code	Strata_ code	CHF_ 2016	CHF_ 2017	CHF_ 2018	CHF_ 2019	CHF_ avg 4 years	CHF_ 2020
9	539	51	0.32	0.6	0.63	0.68	0.56	0.56
57	540	103	0.3	0.6	0.49	0.74	0.53	0.38
168	541	53	0.4	0.45	0.41	0.4	0.42	0.37
168	542	53	0.18	0.34	0.31	0.73	0.39	0.34
168	543	53	0.39	0.46	0.36	0.42	0.41	0.42

4.6 Accounting for end-of-season crop risks (applicable to all models)

There are certain crop risks that need to be accounted separately in modelled yield/CHF because they are not parameterized in the model. Mostly, these are the risks that occur during reproductive stage of crops – flowering to harvest period, during the time window of 30-40 days before harvest. Therefore, Correction Factor approach is developed here to correct the modelled yield/CHF for such risks which include:

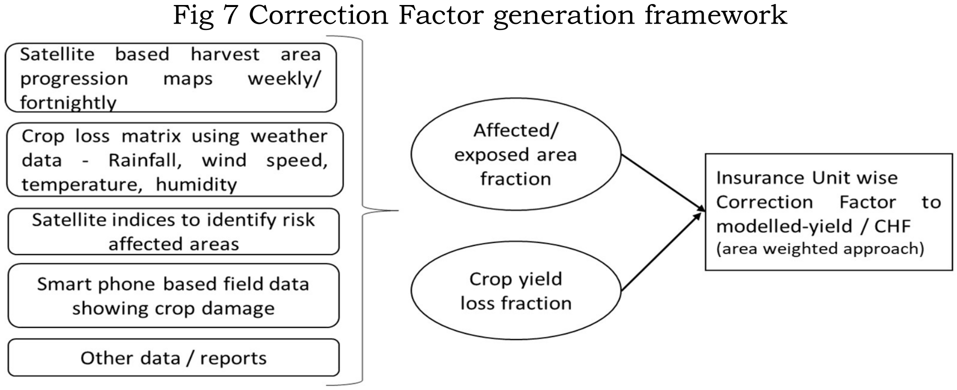
- Unseasonal rains/Floods/Cyclones (submergence, lodging, panic harvest etc)

Weather aberrations such as hot and dry winds, rise in temperatures (poor grain setting and grain development)

- Weather induced pest/disease incidence
- Pest incidence following floods (BPH in rice)

The methodology framework for generating Correction Factor for accounting the impact of crop risks occurring the terminal season, has two components namely (a) detecting the affected/exposed area and (b) crop loss fraction in each Insurance Unit as shown in Fig.7. Affected /exposed area is derived mainly from satellite data using (a) harvest area progression map, (b) anomalies of indices of pre-and post-event and comparison of indices with no-event past years. Yield loss fractions are generated based on weather indices, Mobile based field data.

Fig 7 Correction Factor generation framework



5. Mentor institutes (MITR) for YES-Tech implementation

The mentor organizations for the State to support the YES-Tech program are the Space Application Centre (SAC-ISRO), National Remote Sensing Centre (NRSC-ISRO), North-Eastern Space Application Centre (NESAC-ISRO), and ICAR centres. **These agencies are identified based on their published work on crop yield estimation. State wise list of MITR organizations is given below, and States are advised to select an agency from the list.**

Table 6 List of mentor institutes

S. No.	States	MITR Organisations
1	Andaman and Nicobar Islands	ICAR
2	Bihar	ICAR
3	Himachal Pradesh	ICAR
4	Jammu and Kashmir	ICAR
5	Ladakh	ICAR
6	Lakshadweep	ICAR
7	Puducherry	ICAR
8	Arunachal Pradesh	ICAR/NESAC
9	Assam	ICAR/NESAC
10	Manipur	ICAR/NESAC
11	Meghalaya	ICAR/NESAC
12	Mizoram	ICAR/NESAC
13	Nagaland	ICAR/NESAC
14	Sikkim	ICAR/NESAC
24	Tripura	ICAR/NESAC
15	Andhra Pradesh	NRSC-ISRO
16	Chandigarh	NRSC-ISRO
17	Chhattisgarh	NRSC-ISRO
18	Jharkhand	NRSC-ISRO
19	Karnataka	NRSC-ISRO
20	Madhya Pradesh	NRSC-ISRO
32	Maharashtra	NRSC-ISRO
21	Odisha	NRSC-ISRO
22	Tamil Nadu	NRSC-ISRO
23	Telangana	NRSC-ISRO
25	West Bengal	NRSC-ISRO
26	Dadra and Nagar Haveli and Daman and Diu	SAC-ISRO
27	Delhi	SAC-ISRO
28	Goa	SAC-ISRO
29	Gujarat	SAC-ISRO
30	Haryana	SAC-ISRO
31	Kerala	SAC-ISRO
33	Punjab	SAC-ISRO
34	Rajasthan	SAC-ISRO
35	Uttar Pradesh	SAC-ISRO
36	Uttarakhand	SAC-ISRO

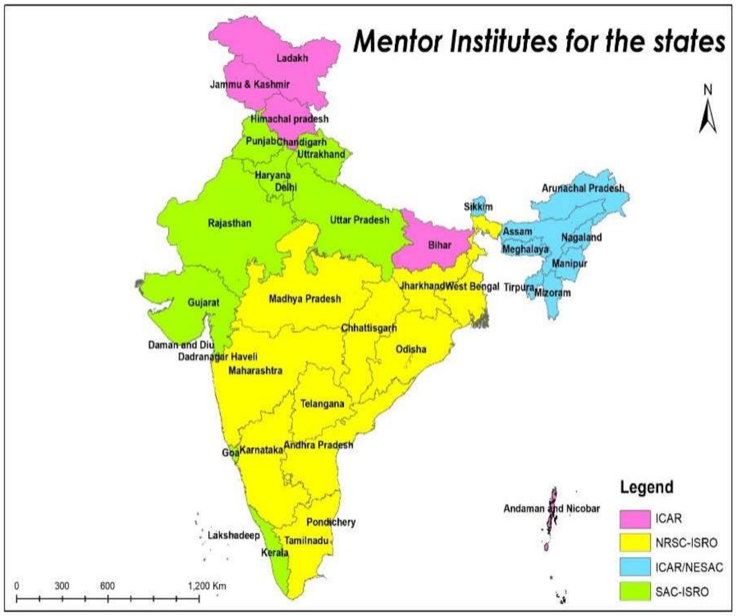


Fig 7: Map showing States and MITR organizations to support YES-Tech.

6. EMPANELMENT OF TECHNOLOGY IMPLEMENTATION PARTNER (ELIGIBILITY & PROCEDURE)

6.1 SCOPE OF WORK

Pradhan Mantri Fasal Bima Yojana (PMFBY) is A yield-based crop insurance scheme that uses Crop Cutting Experiments (CCEs) to determine the yield loss suffered by the farmers due to natural catastrophes and adverse weather conditions. Owing to the lowering of insurance unit level from block level to Village panchayat/GP, the number of CCEs to be conducted has increased manifold. The yield obtained from the CCEs is accurate but laborious and time-consuming which results in delays in the settlement of claims. Further, in the current methodology of yield estimation, the allocation and selection of fields for conducting CCE are based on the information of crops of previous years due to the non-availability of current year information at the time of planning of the survey. As a result, the precision of estimates is affected.

The scope of the current document is to roll out the approaches developed during pilot studies in a large number of districts, at least for two crops, so that gradually the PMFBY can shift to a more technology-based yield estimation regime. The outcome and findings of these activities will be assessed for taking well-informed, more accurate, and unbiased decisions about crop yield at the village/GP level. The overall monitoring of the entire process of this project would be overseen by MNCFC, with technical advice from the Expert Committee formed for this activity.

6.2 ELIGIBLE AGENCIES

This work is open to all technical Agencies, which include government, private, international, and autonomous organizations.

a) ***The Agency can be government/private/autonomous organizations from India or abroad. However, International Agencies should have technical units in India.***
b) The agency should have a permanent/ On-roll Remote Sensing Expert, Agriculture Expert, Data Analytics, Machine Learning, and Artificial Intelligence expert
c) The Agency should have experience in working in at least 5-6 states of the country in different (2-3) crops.
d) Agency should have experience in high-resolution yield estimation and processing of Remote Sensing data.
e) Agency should have experience in using modern tools like Artificial Intelligence, Machine Learning, Crop Models, Decision Support Systems, High-resolution data from satellites & UAVs, etc.
f) ***The Private Agencies/Companies should fulfill the following additional criteria.***
g) ***The Agency must not have been blacklisted by any Government/Ministry/Department/PSU, nor should they have been debarred from dealing with any public Department.***
h) ***The firm must be registered with all Government/statutory authorities such as the Sales Tax Department, Income Tax Department, etc. as required in the normal course of business to render providing similar services.***

6.3 CRITERIA FOR EMPANELMENT

The criteria for the empanelment of the agencies are mentioned below:

Proven agencies:

i. Agency should have the experience to carry out the crop damage & yield estimation using Technology for **Rice in Kharif and Rice/Wheat in Rabi** in at least **25 districts, well distributed in 4-5 states** of different agro-climatic conditions in the previous three years.
ii. The approach developed by the agencies should have been calibrated and validated by the Government of India/State Department of Agriculture/Revenue.
iii. Apart from these, the agency should also adhere to the criteria assigned for 'New agencies' stated below:

6.4 New Agencies:

i. Agency should have the experience to carry out the Crop damage & yield estimation using Technology for **Rice in Kharif and Rice/Wheat in Rabi** at the lowest administration unit level in the previous three years.

ii. The approach has been tested/used by the State/insurance companies/central government agencies/PSUs etc.The agency must be well-versed in innovative technologies i.e. Remote Sensing, AI/ML, IoT, and Advance Simulation tools.

iii. The agencies must be having proper Manpower Resources i.e. Lead Experts, Remote Sensing Experts, GIS Experts, Statistics Experts, Agriculture Experts, Data Science & Modellers, and Software Developers on their role, minimum of 25 experts.

iv. They should have in-house remote sensing and data processing capability (well-equipped lab).

v. The agency must have the in-house capability as specified in YES-TECH SOP.

vi. The agency should have in-house capability of developing of Mobile Application, Web-based portal for data collection and dissemination in real-time.

vii. The agency should have experience in the collection of at **least 10,000 ground-based observations such as Ground truth, Crop Photographs, and Crop Cutting Experiments.**

viii. The agency should have a minimum annual turnover of 50 lakhs **(average) in the last three years** specifically related to similar activities.

ix. The agency should not be blacklisted/debarred by any Government/PSU organizations.

x. The agency should have peer-reviewed scientific publications.

6.5 SELECTION CRITERIA

The selection of the Agency will be made, by the Expert Team, based on the technical specifications. The minimum qualifying mark will be 70 out of a maximum of 100 (hundred marks) as a benchmark for the quality of the technical proposal. The various criteria based on which the technical proposal will be evaluated are given below.

Table 7: Marking Criteria for Technical Evaluation

SN	Parameters	Explanation/Details
1	**Experience of the Company in similar work (Max. 30 marks)** (*Documentary proofs to be submitted*)	Experience can be in the form of crop yield estimation, satellite & UAV data processing, Crop Model Development/Use, and Advanced Data Analytics (AI/ML) 10 marks will be given for each year of experience.
2	**The capabilities to handle innovative technologies (Max. 20 Marks)**	• Use of high resolution (10m or better) optical satellite data: 2 Marks • Use of SAR data: 2 Marks • Use of AI/ML Tools: 2 Marks

	(*Detailed methodology should be given showing the specific technology to be used*)	• Smart Sampling for CCEs, using satellite and other data:2 Marks • Field Data Collection using smartphones and their use in the yield models: 2 Marks • AI-based Analysis of field photographs: 2 Marks • Use of UAVs for sample locations (at least 25 sq km) and their use for validation: 2 Marks • Use of IoT/Sensor Data: 2 Marks • Use of Advanced Statistical Models: 2 Marks • Use of RS-based physical models (e.g. LUE models): 2 Marks • Use of Crop Growth Models (with RS inputs): 2 Marks (*Total of this is 22, however maximum mark to be given is 20*) Documentary proof indicating the use cases needs to be submitted by the agency
3	**Technical facility available with the Agency to handle the analysis for at least 200 districts in a season (Max.10 Marks)** (*Complete details with specifications and documentary proof may be provided*)	• Computer Lab having workstations with a minimum of 25 High-end systems (in-house): maximum 2 marks. • Software (02) for IP&GIS for satellite & UAV data processing: maximum 2 marks • Separate Storage Space (NAS/SAN/Cloud): maximum 2 Marks • In-house GIS Portal: 1 Mark • AI/ML Software Tools: 1 Mark • Crop Modelling Tools: 1 Mark • Mobile App for Field Data Collection, with pictures & geo coordinates: 1 Mark
4	**Qualification of Technical personnel available with the Agency (Max.10 marks)** (*Details to be given with name, designation, qualification and mobile number*)	2 marks each for number of PhD holders in RS&GIS/Agriculture/Data Analytics/IT/ Statistics/Mathematics 1 Mark each for number of Masters Degree holders in the above subjects.
2	**Patents or reputed publications of the technology proposed to be used (Max. 20 Marks)** (*Detailed list to be provided*)	For each publication (peer-reviewed journal/Government approved report), in a related field, 2 marks will be given. For each patent in a related field 5 marks will be given (only accepted patents will be considered)
6	**Planning of the study (Max.10 Marks)**	• Diversity of study area (both Geographically and agro-climatic zone wise): Max 2 Marks • Statistical soundness of the experimental design: Max 2 Marks • Feasibility of the Study (based on proper manpower, technology and facility deployment): Max 2 Marks • Availability of detailed time schedule: Max 2 Marks • Planning for Validation: Max 2 Marks
	Total = 100	

The Agencies who are qualifying as per the technical evaluation criteria will be considered technically competent and would be considered for the empanelment to support the nationwide rollout of technology-based yield estimation under PMFBY.

MNCFC can consider empanelment of agency for this work to multiple agencies if the agencies are technically competent.

Agencies need to submit the following documents.

i. Certificate of Incorporation/Registration.
ii. Copy of PAN/TAN/GST numbers.
iii. Copy of Service Tax Registration Certificate
iv. Copy of Income Tax Return for the last three Financial Years i.e. FY 2019-20 and 2020-21 and 2021-22.
v. Solvency Certificate
vi. Audited accounts (Balance Sheet and Profit and Loss Account etc.) for the last three years.
vii. Copies of Work Contracts (of similar services) of minimum Rs. 50 Lakh per annum, from Government/Autonomous bodies/PSU, Private entities during last 3 years, including satisfactory performance certificate, if any
viii. Certificate by the Agency to the effect that the Company is not blacklisted by any Govt. Organization/ DGS&D/ NCCF / PSU.
ix. RFP Acceptance Letter on Company's letterhead which should be filled, signed, and stamped/certified properly.

Additional documents to be provided

a) **Undertaking for the Study**. A certificate of Undertaking that the Agency will carry out the work as per YES-Tech Guideline.
b) **Certification.** The Agency should provide certificates of past experience in conducting similar kinds of studies.
c) **Documentation.** The Agency should provide detailed work plan.
d) **Earlier Experiment.** The Agency should provide a report of earlier similar experiments conducted by it. The agency also should provide details of observations collected using a similar observation system.
e) **Non-Disclosure Agreement (NDA).** The Agency should provide an NDA.

7. MODEL TENDER DOCUMENT

SELECTION OF AGENCY

[Through Quality and Cost Based Selection "QCBS" method]

REQUEST FOR PROPOSALS (RFP)

RFP No.:

Hiring of Consulting Services for:

"Technology-based yield estimation at GP level in the state of <name>

NOTICE INVITING RFP For the Selection of Agency	
Assignment name	**Hiring of Consulting Services for:** Technology-based yield estimation at GP level in the state of **<state name>**
Office of issue	
RFP Number	
RFP Available at	
Date of Publishing	
Proposals submission date	-
Pre-bid queries submission last date	
Pre-bid meeting date and time	
Expected date for the commencement of theServices	

On behalf of the President of India, a Request for proposal is invited from experienced agencies for **Technology-based yield estimation at the GP level in the state of <state name>,** for the**<season, year>**

*The RFP can be uploaded online on **<website>** and copies can be sent throughemail to* ***<email-ID>***

<Authorized signatory >

<Department name,
address>

General aspects of RFP

1. Introduction and background

This RFP is for obtaining services of reputed technical/research agencies for Gram Panchayat level Crop Yield Estimation Using specified Technology/models <……crop> for Pradhan Mantri Fasal Bima Yojana (PNFBY). The study should be carried out for <……crop> during <season year> and <season year>, and may be extended depending upon the requirement of <Issuing organization/authority name>.Presently, services are required for Gram Panchayat (GP) level Yield Estimation using Technology in at least <number of districts> well distributed in at least <number of states> of different agro-climatic zones for <seasons>**.** Each agency has to take at least <number of districts> districts. <Issuing organization/authority name> <number of districts> <seasons>.

2. Eligibility criteria for agencies

The agencies which are empanelled by MNCFC will only be eligible to participate in the financial bids called by the states/UTs for implementation of **Technology-based yield estimation at the GP level**.

3. Financial Proposal:

State/UTs will call for an annual or season-wise financial bid at State level for the pre-selected Technology Model and for proposed crops. The selection of bidders will be based on L1 evaluation of the offered total cost.

4. Criteria for work

The criteria for conducting yield estimation are mentioned below:

I. Agency should carry out the work of all the Insurance Units in at least, <number> districts. The number may change depending on the future requirement.
II. The districts should be well distributed as per different risk zones.
III. The study should be conducted for <Paddy> crops, in the entire tender period.
IV. Insurance Unit having an area of at least 10 ha must be covered.
V. Well-distributed minimum 160 CCEs per district **(for model calibration and validation)** with a gradual decrease in the number of field experiments YoY for validation of the model, as per need.
VI. Specific parameters (supplementary to ground truthing): crop variety, sowing/harvesting dates, agrotechnical activities

(fertilizer/pesticide use, watering dates), pest & diseases Annexure-2 gives the guidelines for conducting CCEs, which can be used by the Agency However, selected Agency should compulsorily monitor all the CCEs and also participate in at least 40% planned CCEs. Data of CCEs will be sent to <by issuing organization/authority through App on a real-time basis.

VII. Separate models should be developed for all the IUs, also separately for irrigated and unirrigated.

VIII. The Satellite-based crop classification should use data of 5-30m spatial resolution. Both microwave (SAR) and optical remote sensing data be used, as per the requirement.

IX. Crop classification accuracy (overall accuracy) should be at least 80 per cent. At least 400 (200+200) Ground truth points per district/season should be used to cover all growth stages of all standing crops with gradual decrease in number of collected data YoY.

X. Technology proposed to be used should be specified technology models only and the parameters should be selected as per the YES-Tech manual.

XI. The final study report, for <season>, needs to be submitted by <expected date, year> and for <season>, needs to be submitted by <expected date, year>The Report format is provided in Annexure III.

XII. The Mid Term Report should be, for <season, by <Date>and for <season, by <Date>. However, the Agency should provide interim reports, as and when asked, and also provide regular updates, through a special portal designed for the purpose.

XIII. The selection of the agency will be done by an expert committee, as per the selection criteria.

XIV. The expert committee may reject any proposal, if not found suitable/not meeting with the criteria.

5. Expected Technology implementation

The Agency should use the technology specified in YES-Tech Manual only.

6. Format for RFP to be submitted by the agency

1. A brief description of the agency's background mentioning the address of its registered head office, the address of the local office in Delhi, contact no. (Mobile, landline, fax and email id), names of important persons who may be contacted etc.
2. Agency's experience: list of similar as well as successfully executed projects.
3. Description of yield estimation technology
   - Technical methodology and approach
   - Work plan: Specify the key activities/tasks of the assignment will be

carried out, including their duration, scheduling, and potential delivery dates for the reports

- Study Area, intended to be taken up.
- Crops to be taken
- Experimental Setup
- Timeline
- Expected Results, Outputs, Deliverables
- Lists of Patents/publications in the similar works

7. Additional information/document to be provided

The Private Agencies/Companies should fulfil following additional criteria (self-certificate onletter head).

i. The Agency must not have been blacklisted by any Government/ Ministry/Department/PSU, nor should they have been debarred from dealing with any public Department.

ii. The agency must be registered with all Government/statutory authorities such as Sales Tax Department, Income Tax Department, etc. as required in the normal course of business to render providing similar services.

The Private agencies should have to provide following additional documents:

a) Certificate of Incorporation/ Registration of Agency/ Memorandum and Articles of Association/Partnership Deed/ Proprietorship Deed/ Declaration of Proprietorship etc. as the case may be.

b) Copy of PAN/TAN numbers.

c) Undertaking for the Study. A certificate of Undertaking that the Agency will carry out the study as specified in the Section 4 & 5.

d) Certification. The Agency should provide certificates of the past experience of conducting similar kind of studies. Copies of experience certificates/order for award of contract for related services with other Ministries/Departments RFP Acceptance Letter on agency's letter head which should be filled, signed and

e) stamped/certified properly.

f) Bid security (EMD) of <Amount in Rs.> or registration certificate of the Central Purchase Organization, or NISC.

The aforementioned documents must be correctly scanned so that they are clearly readable and intelligible since otherwise, the RFP may become technically unresponsive. The documents should be organized precisely in the above order and page-numbered, with an index at the front that lists each document's page number.

8. EMD/BID security (Only for Private Agencies)

I. Agencies/Bidders, except those who are registered with the Central Purchase Organization, National Small Industries Corporation (NSIC), shall have to furnish, as part of bid, an EMD/bid security for an amount of <amount in INR> <amount in words> in the form of an account payee Demand Draft, Fixed Deposit receipt, Banker's Cheque or Bank Guarantee from any Indian Commercial Bank in favour of <addressing authority> <address> valid for a period of 45 days beyond the final RFP validity period and shall be delivered physically to Head of Office, <issuing Organization name/authority and address>**,** on or before the last date and time fixed for RFP submission.

II. The RFP not accompanied by EMD/RFP security shall be rejected being non-responsive at the bid opening stage and returned to the bidder unopened.

III. The bid security of the unsuccessful bidder will be discharged /returned to the bidder at the earliest after evaluation of the bid and latest on or before the 45th day after the award of the contract.

IV. The successful bidder's bid security will be discharged upon the bidder's acceptance of the award of contract and furnishing the performance security.

V. The bid security may be forfeited:

a. If a bidder withdraws his bid during the period of bid validity specified above.

b. In the case of a successful bidder, if the bidder withdraws or amends the RFP or impairs or derogates from the RFP.

9. Performance bank guarantee (only for private agencies)

The PERFORMANCE BANK GUARANTEE is approximately 20% of the cost of the project. PBG will be taken in 2 instalments i.e. one instalment in <season name> and one instalment in <season name>. The amount shall be remitted through Account Payee DD/Fixed Deposit Receipt (FDR)/Bank Guarantee in favour of "Pay & Accounts ………………………………" towards Performance Bank Guarantee (PBG). The PBG shall be valid for at least 90 (Ninety) days beyond the completion of contract period and shall be denominated in Indian rupees payable at New Delhi, issued by a scheduled bank in India through its branch in New Delhi, India. The proceeds of the performance security shall be payable to <name of issuing organization> as compensation for any loss resulting from the service provider's failure to complete its obligations under this RFP. <name of issuing organization> shall notify the service provider in writing of its invocation of its right to receive such compensation within 15 days, indicating the reasons for which the service provider is in default. The performance security shall be discharged by <issuing Organization name/authority and address> and returned to the service provider within 30 days from the date of final certificate, certifying the fulfilment of the performance obligations under this RFP. The service provider shall furnish amendment to the performance security, if required, within 15 days of notification.

List of crops (The agency has to select one crop form each group)

Group	Kharif <Year>	Rabi <Year>
1	<Crop Name>	<Crop Name>
2	<Crop Name>	<Crop Name>
3	<Crop Name>	<Crop Name>

Special Conditions in selection of Crops and districts:

Agency selected earlier for the similar Pilot studies for estimation of Crop Yield at GP level using technology during <Year>, will not select combination of same location, crop(s) and methodology during <Year>.

Annexure-2: Guidelines for conducting CCE for Ground Truthing

Annexure-3: Report format

i. Executive Summary
ii. Contents with Page Numbers
iii. List of Tables
iv. List of Figures
v. List of Annexures
vi. List of Contributors

1. **Introduction** (This should have review of literature, with references)
2. **Study Area** (Description with maps)
3. **Data Used**
   - Ground Data (Crop Survey, CCE, Soil, Weather Data, any other data) – Summary Tables should be provided for each
   - Satellite Data (Descriptions with number of scenes and dates of Data)
   - Details of Any Other Data
4. **Methodology**
   - Field Data Collection
   - Satellite Data Processing for crop map and areas
   - Smart Sampling and CCE data Collection
   - Yield Modelling
   - Accuracy Evaluation (RMSE, NRMSE, t-test, MAPE, correlation coefficient, Index of Agreement, etc.)
5. **Results and Discussion**

- Description of field data (summary tables with statistical analysis and any interpretation)
- Crop Area Estimations (Statistics, Maps and accuracy)
- Suitability of Smart Sampling (Stratification Efficiency)
- CCE data description
- Yield Estimation and its evaluation

6. **Summary and Conclusions (including way forward)**

7. **References** (at least 20, please follow the reference format of Journal of Indian Society of Remote Sensing)
8. **Annexures** (Tables of all data details, which are being transferred **to** < issuing Organization /authority name>.