Mid-Season Report

on

Implementing YESTECH for Kharif rice in Andhra Pradesh.

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Mid-Season Report on Implementing YESTECH for Kharif rice in Andhra Pradesh. 2025-26

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14	Abstract (with keywords) :	The Department of Agriculture & Farmers Welfare (DA&FW), Government of India, has launched the YESTECH programme under the Pradhan Mantri Fasal Bima Yojana (PMFBY). As part of this initiative, the Agriculture Department of Andhra Pradesh has adopted a semi-physical model approach, as detailed in the YESTECH Manual (2023), for crop yield estimation. The department has decided to implement this technology-based approach in five districts: Eluru, East Godavari, West Godavari, Konaseema, and Nellore. The programme is scheduled for implementation during the Kharif season 2025–26. This Mid-season report outlines the data sources and methodology used for rice crop classification and mapping and related results like rice crop mask, rice crop stress, and planting dates, the approach for yield estimation of Kharif rice using the semi-physical model, the expected outcomes, and key references. Key words: YESTECH, PMFBY, kharif-rice, crop map, yield estimate, insurance unit, Satellite data, Semi-Physical model.		

1 Introduction

1.1 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 the following gaps: (a) a limited number of measurements, (b) a time-consuming process, and (c) vulnerable to human errors.

1.2 The Department of Agriculture & Farmer Welfare (DA&FW), Government of India (GOI) has taken up many initiatives to improve crop yield estimation procedures ever since the launch of Pradhan Mantri Fasal Bheema Yojna (PMFBY). Technology development agencies of both the Government and Private sectors have been engaged in developing new yield estimation methods using various datasets and models such as 1. Semi-physical model, 2. Machine learning approach, 3. Crop simulation model, 4. Ensemble model, and 5. Parametric index of crop performance (CHF model) through pilot studies.

1.3 Towards enabling large-scale adoption of technology-based yield estimates in the PMFBY system for crop loss assessment, DA&FW has conceptualized a special initiative, the “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 the 2023 season onward. An SOP (Standard Operating Procedure) has been developed by DA&FW, GOI to estimate yield at the Insurance Unit level.

1.4 In Andhra Pradesh state, the state Agriculture Department, Government of Andhra Pradesh is the implementing agency of the YES-Tech program. The program was initially piloted in Kakinada and Nandyal districts during the Kharif seasons of 2023–24 and 2024–25, with the Andhra Pradesh Space Applications Centre (APSAC) serving as the Technical Implementation Partner (TIP). Following the successful implementation and encouraging results, APSAC is continuing the implementation of the program in these two districts during Kharif 2025–26 as well.

During Kharif 2025-26, the Agriculture Department has decided to expand the YESTECH program to five additional districts: Eluru, East Godavari, West Godavari, Konaseema, and Nellore. For this expanded rollout, ICRISAT has been designated as the Technical Implementation Partner-2 (TIP-2). The Space Applications Centre (SAC-ISRO), Ahmedabad is acting as the Mentor Institute for Technology Rollout (MITR) for the YESTECH program in Andhra Pradesh, providing technical guidance and oversight.

1.5 The objectives of the project are:

a. To generate rice crop mask based on satellite remote sensing data.
b. To estimate yield of Kharif rice at insurance units (IU) level in Eluru, East Godavari, West Godavari, Konaseema, and Nellore districts of Andhra Pradesh using semi-physical model.

2 Review of Literature

2.1 Predicting food grain yields earlier can help farmers and policymakers plan accordingly. Accurate statistical data on yield production availability assists planners in making strategic decisions and regulating import and export activities. However, the traditional crop area and yield estimation approach, which requires a huge labour force, is time-consuming, inaccurate, and practically difficult to apply on a broad scale (Tripathy *et. al.*, 2014, Dwivedi *et. al.*, 2019, Ali *et. al.*, 2021, Pazhanivelan*et. al.*, 2022).

2.2 In India, the Crop Cutting Experiments (CCE) is operational for the crop yield estimation at Insurance Unit level. The CCE is a traditional approach employed by governments and agricultural bodies to accurately estimate the yield of a crop where sample locations are selected based on random stratified sampling. The conventional CCE approach is not without flaws, the biggest drawback of this traditional method is that it is dependent on a few variables such as administrative setup, type and size of the field staff, farmer cooperation, and harvest conditions. Especially in a scenario where there are nearly 2.5 lakh gram panchayats in India that are scattered, along with inadequate trained human labour for yield estimation within the short harvesting window (https://indiaai.gov.in/article/how-ai-is-used-to-streamline-pradhan-mantri-fasal-bima-yojana). The increasing number of CCEs for conducting a crop yield estimation, which results in time-consuming, redundancy, and rise data uncertainty issues. Since the harvest time is very short, carrying out a few CCEs is extremely difficult with limited manpower and time.

2.3 Using advanced technologies to bring optimize the solution for minimizing CCEs of the insurance unit level (village, village panchayat, block, revenue circle, Mandal, or taluk) is essential for overall crop management practices for yield prediction. Further, to optimize the CCEs, a technique for the CCE site selection using yield proxy derived from the remote sensing based Semi-Physical model was implemented during 2019-20(Source: Protocol of smart sampling for crop cutting experiments, 2019, Department of Agriculture, Coop. & Farmers' Welfare, Ministry of Agriculture & Farmers' Welfare, Government of India, New Delhi – 110001, September, 2019). The chosen semi-physical model was demonstrated at district and state level yield estimation (Tripathy *et. al.*, 2014) and further refined for its application in estimating yield of different crops including rice and wheat at gram panchayat scale (Tripathy *et. al.,* 2022, Dwivedi *et. al.,* 2019).

2.4 For the rice crop mapping, two primary methodologies are employed for mapping extensive paddy rice cultivation areas using satellite remote sensing data. The first approach relies on multi-temporal observation data, predominantly employing statistical models or index-based methods (Singha *et. al.* ,2020; Yang *et. al.,*2021). Given the distinctive phenological characteristics of paddy rice, such as flooding and transplanting, these features are widely utilized for precise paddy rice identification (Yin *et. al.,*2019).

2.5 The second approach utilizes single observation data in conjunction with machine learning classifiers (Onojeghuo *et. al.*, 2018; Zhang et. al., 2018b; Cai *et. al.*, 2019). Classifiers like Random Forest, Support Vector Machine, or Decision Trees are chosen to extract relevant features, followed by the classification process. While these methods are effective in identifying paddy rice from Landsat images, the feature extraction step heavily depends on domain knowledge and expertise, potentially missing intrinsic subtle features and lacking the desired flexibility (Xu *et. al.,*2021).

2.6 So, understanding the limitations of automation and manual way of identifying the crop, the study is utilising the semi-automatic classification procedure which include unsupervised classification followed by class labelling using spectral matching techniques.

3 Study Area

The agriculture department has selected "Semi-Physical" model (YESTECH manual) of yield estimation for Rice crop yield estimation at Insurance Unit level (Village level) in extended five districts namely, Eluru, East Godavari, West Godavari, Kona Seema, and SPS Nellore of Andhra Pradesh. The spatial map of study area is shown in Figure 1.

3.1 East Godavari

East Godavari experiences a tropical climate with moderate to high humidity during the Kharif season. Temperatures commonly range between 25°C and 32°C, with May–June peaks occasionally reaching 48°C. The district's normal annual rainfall is approximately 1,219 mm, most of which arrives during the southwest monsoon from June to September. Crops such as rice and cotton dominate, supported by fertile delta soils and extensive irrigation infrastructure. The district is also prone to drought and occasional cyclonic flooding during harvest time.

3.2 West Godavari

West Godavari has a tropical, deltaic climate with hot dry summers and moderately mild winters, typical of Coastal Andhra. Summer temperatures often exceed 40°C, while during Kharif, day-time highs usually fall between 30–32°C. Average annual rainfall ranges around 976–1,015 mm, with approximately 60% falling during the southwest monsoon (around 642 mm). Major Kharif crops include rice, cotton, and sugarcane, benefiting from a well-developed canal and reservoir-based irrigation system across the Godavari delta.

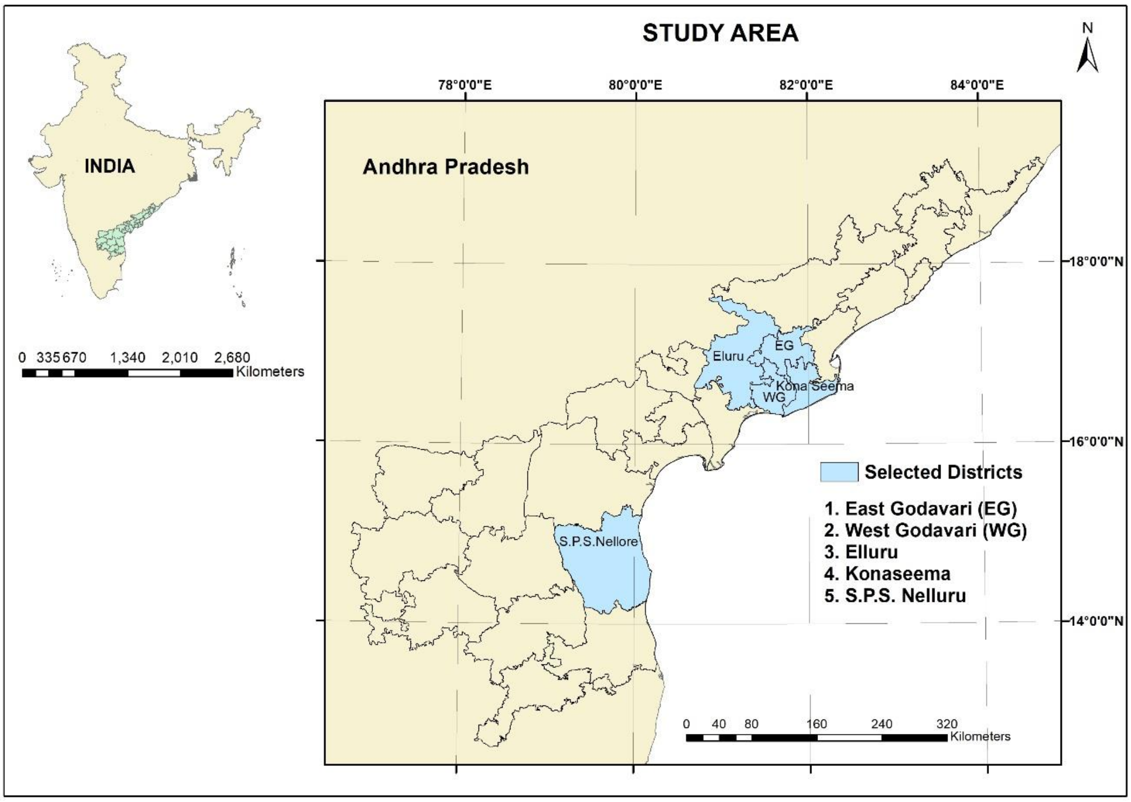


Figure 1: Study Area

3.3 Eluru

Eluru lies inland within the Coastal Andhra plains and shares a hot, humid tropical climate like its neighbours. Summers can exceed 40°C, with an average annual temperature of about 28.2°C. The district receives around 992 mm of rainfall annually, with maximum precipitation in July–August, coinciding with monsoon onset. Rice is the dominant Kharif crop, supported by proximity to Kolleru Lake and the Eluru Canal system used for irrigation; cotton is also grown on parts of the plain.

3.4 Konaseema

Konaseema, formed from Southeastern parts of East and West Godavari, has a tropical deltaic climate like adjacent districts, with hot and humid conditions during Kharif. Average rainfall aligns with East Godavari norms (~1,200 mm), concentrated in the southwest monsoon. Fertile soils along the Godavari delta support rice cultivation predominantly, with coconut, banana, and other plantations thriving under irrigation canals. Occasional cyclonic rainfall during monsoon withdrawal affects late crops and harvesting.

3.5 SPS Nellore

Nellore experiences a tropical savanna climate (Köppen As/Aw) with hot, humid summers and moderate winters. Maximum summer temperatures reach 36–40°C, while minimum winter—Kharif—temperatures stay between 23–25°C. The district's average annual rainfall is around 1,080 mm, of which nearly 60% falls during the northeast monsoon (October to December); southwest monsoon contributes less. Rice is the major Kharif crop, along with cotton and pulses; the district also faces both droughts and floods, especially during cyclonic events associated with northeast monsoon showers.

4 Dataset used

For the Rice crop yield estimation during Kharif 2025-26, the basic input indicators for Semi-Physical model are the Fraction of absorbed photo synthetically active radiation (fAPAR), Photo synthetically active radiation (PAR), Radiation use efficiency (RUE), Water scalar, Temperature Scalar and Harvest Index (HI) data, which will be used for yield estimation. The rice crop map, representing the area of interest, will be generated using cloud-free Sentinel-2 (MSR) data. In the absence of suitable optical data, Sentinel-1 SAR data will be utilized for crop classification. To generate these input indicators the following data sets are required. The details of data product, satellite/sensor, and source are given in the Table 1.

Table 1: Details of input data and source

Data /Product	Purpose	Satellite/ Ground	Sensor	Resolution	Source
Surface Reflectance data	Rice Crop Mapping	Sentinel-2/ Sentinel-1	MSI/SAR	10m/ 20m	**ESA** (European Space Agency) https://dataspace.copernicus.eu/
Daily integrated Insolation	PAR	INSAT 3DR	Imager	4km	**MOSDAC-ISRO**. https://mosdac.gov.in/
FAPAR	FAPAR	Terra	MODIS	0.5km	**NASA-** EARTHDATA. https://earthexplorer.usgs.gov/

Surface Reflectance data	LSWI, Water Scalar, Planting Date.	Terra/ Sentinel-2	MODIS/MSI	0.5km./ 20m./ 10m.	**NASA**-EARTHDATA. https://earthexplorer.usgs.gov/ **ESA** (Europian Space Agency) https://dataspace.copernicus.eu/
Past year/current CCE data	Harvest index	Calibration with past year data		District Level	Agriculture dept. (GoAP)/ICRISAT
RUE_{max} (Maximum Radiance Use Efficiency)	The RUE_{max} for the major cultivar will be taken from literature in consultation with SAC.				

5 Methodology

The methodology includes five major steps. 1. Field data collection, 2. Crop mapping, 3. Crop condition monitoring and 4. Crop yield estimation and 5. Accuracy estimation. The methodology flowchart is shown in figure 2.

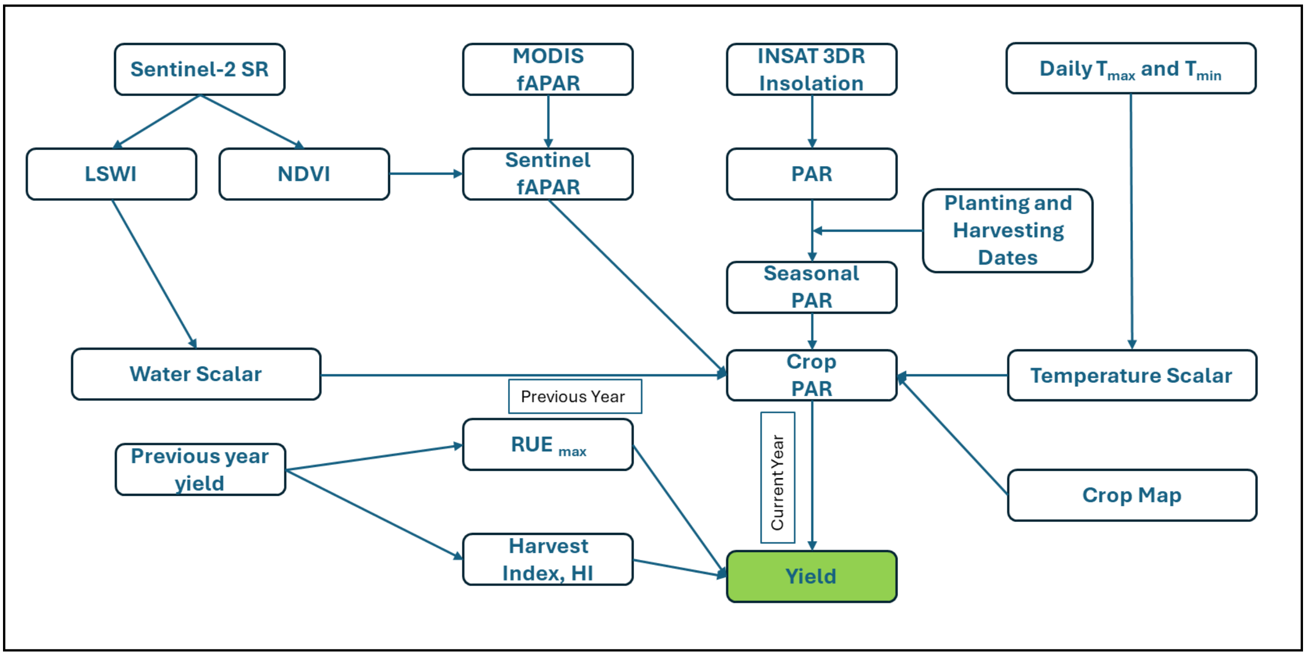


Figure 2: Semi-physical model framework

The semi-physical model 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 (BM) 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 is used as a limiting factor of crop yield. Model framework (flow chart) is furnished in figure 2.

5.1 Ground truth data for rice crop mapping and accuracy assessment of rice map

ICRISAT team collect ground truth observations from study districts; Eluru, East Godavari, West Godavari, Konaseema, and SPS Nellore of Andhra Pradesh, with a minimum of 150 points from each district covering rice fields as well as other LULC. The ground data is collected based on the spectral variations generated using sentinel-2 NDVI imagery till date. Polygon-based samples will be collected using *KrishiMapper*, a geospatial mobile and web application developed by the Ministry of Agriculture and Farmers Welfare, Government of India. Along with ICRISAT will use our field data collection application, ICROPS, which has developed by the RS-GIS Team of ICRISAT. The idea for ICROPS emerged from the need for a simple and reliable tool to capture ground-truth data which was designed with user requirements in mind: lightweight, intuitive, and able to function offline in areas with limited connectivity. Its core features include geo-tagged data entry, drop-down menus to minimise manual errors, and real-time syncing when internet access is available.

The sample locations will be carefully selected considering the variability of different crops as observed on optical satellite data. These samples will be used as reference data for unsupervised classification labelling and accuracy assessment of the rice map.

5.2 Rice map generation

Crop-type classification will be carried out using a semi-automatic workflow that combines satellite data processing, spectral analysis, and ground-truth integration (Figure 3). This approach balances automation with expert intervention to ensure both scalability and accuracy.

5.2.1 Satellite Data Pre-Processing

The classification process begins with the acquisition and preprocessing of multi-temporal satellite imagery, typically from sensors like Sentinel-2 or Landsat. Key preprocessing steps include:

- Cloud masking and atmospheric correction
- Stacking multi-spectral bands over the crop growing season
- Generating maximum NDVI composites at monthly or fortnightly intervals to capture crop phenological patterns

This processed dataset forms the basis for further analysis and classification.

5.2.2 Unsupervised Classification and Pre-Clustering

An initial unsupervised classification is applied to group pixels with similar spectral behaviour. This helps identify broad land cover categories and guides the selection of representative training samples. These pre-clusters also help isolate noise and identify spectral confusion zones that may need further ground validation.

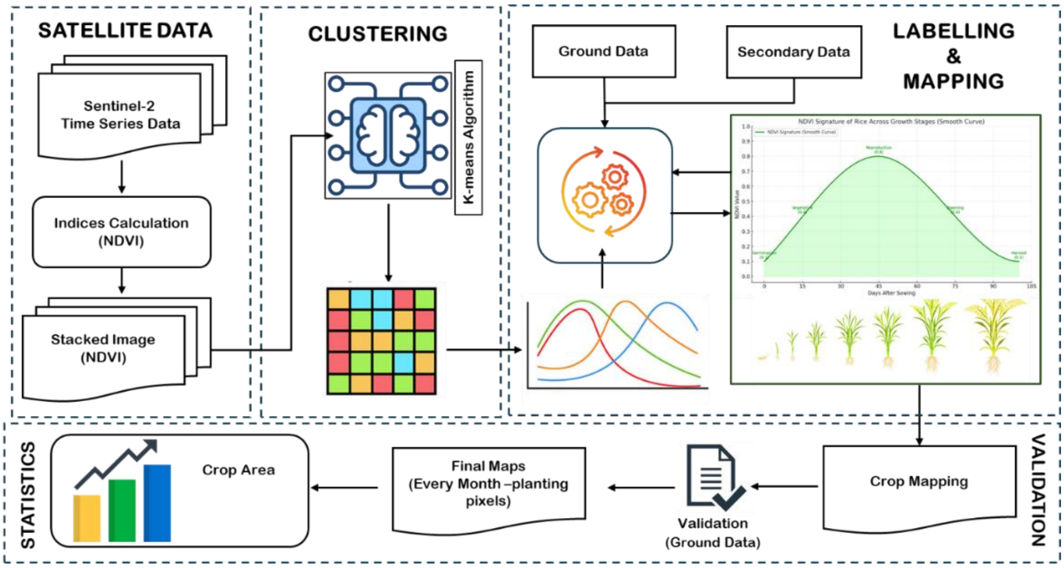


Figure 3: Methodology for crop classification

5.2.3 Development of Spectral Signatures

With support from field data collected using the ICROPS mobile application, spectral signatures are developed for each crop type (e.g., rice, maize) and for other land use/land cover (LULC) classes (e.g., water bodies, fallow, settlements). The process involves:

- Extracting pixel values for ground-verified locations
- Analysing NDVI and other spectral indices over time
- Generating class-wise temporal spectral profiles

This step ensures that each class has a distinct and biologically meaningful spectral identity.

5.2.4 Spectral Matching Techniques

Using the developed signatures, spectral matching techniques are employed to identify and classify each pixel into its most likely crop or LULC class. This step is refined using:

- Field-collected training data
- Secondary datasets such as crop calendars, administrative records, and historical land cover maps
- Expert knowledge to adjust thresholds or resolve class confusion (e.g., rice vs. wetlands)

5.2.5 Accuracy Assessment

To ensure the reliability of classification outputs, an accuracy assessment is conducted using an independent set of ground-truth points that were not used in the training phase. This involves:

- Generating a confusion matrix
- Calculating key accuracy metrics: Overall Accuracy, User's Accuracy, Producer's Accuracy, and Kappa Coefficient

This validation step is crucial for reporting confidence levels and for integrating outputs into decision-support systems.

5.3 Vegetation Condition Index (Rice crop condition assessment)

The Vegetation Condition Index (VCI) at village level has been carried out to assess the rice crop condition. To generate VCI, the current period values of vegetation values was compared with long-term data (at least ten years). The VCI compares the observed NDVI to the range of values observed for the same period in previous years. The VCI is expressed in percentage (%) and gives an idea of where the current value is placed within the extreme values (minimum and maximum) in the historical datasets normalized to a scale of 0 – 100%. Lower and higher values indicate bad and good vegetation conditions, respectively. VCI for NDVI and NDWI are calculated using the formula given below:

$$VCI(NDVI) = \frac{(NDVIcurr - NDVImin)}{(NDVImax - NDVImin)} * 100 \quad \ldots\ldots\ldots\ldots\ldots 1$$

Whereas 'curr' refers to the current period value, 'min' and 'max' refer to the minimum and maximum values of vegetation indices in the historical dataset for the same period and same location. The threshold values of VCI for crop condition assessment can be used as given in Table 2.

Table 2: Classification of Vegetation Condition based on VCI value

VCI Value (%)	Vegetation condition category
60-100	Normal
40-60	Moderate
0-40	Severe

5.4 Rice crop yield estimation using semi-physical model

The SOP (Standard Operating Procedure) is mentioned in the YES-TECH manual for semi-physical model. The semi-physical model 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 (BM) 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. The major inputs for the model are, PAR, FAPAR, Water scalar, RUE max and HI. Water Scalar derived from satellite images is used as a limiting factor of crop yield. Temperature stress has been estimated at village level using state Automatic Weather Station (AWS) data. HI for each IU was derived using the past yer data through calibration of the semi-physical model. Model framework (flow chart) is furnished in figure 2.

5.4.1 Planting date

(i) The planting date at pixel level was derived from the time-series NDVI data, using ISODATA classification and polynomial curve fit method.

5.4.2 Photosynthetically Active Radiation (PAR)

(i) PAR ($MJ \bullet m^{-2} \bullet d^{-1}$) is 50% of the Insolation (Tripathy et.al., 2022) and is derived from the daily insolatio product from INSAT3DR.

5.4.3 Fraction of Absorbed Photosynthetically Active Radiation (fAPAR)

(i) MODIS FAPAR data with 8 days interval has been utilised for generation of FAPAR in this study.

5.4.4 Water Scalar using LSWI (Land Surface Wetness Index)

(i) LSWI index computed from the near range Infrared band and short-wave infrared (SWIR) region around 1610 nm of electromagnetic spectrum. This index is sensitive for the total amount of vegetation liquid and also for soil background.

$$LSWI = (NIR-SWIR)/(NIR+SWIR) \quad ....2$$

NIR=Reflectance in Near Infrared,

SWIR= Reflectance in shortwave Near Infrared

Water Scalar:

(ii) Estimated LSWI is used further in deriving the water stress scalar.

$$W\ Scalar = (1+LSWI)/(1+LSWImax) \quad ....3$$

5.4.5 Harvest Index (HI) estimation

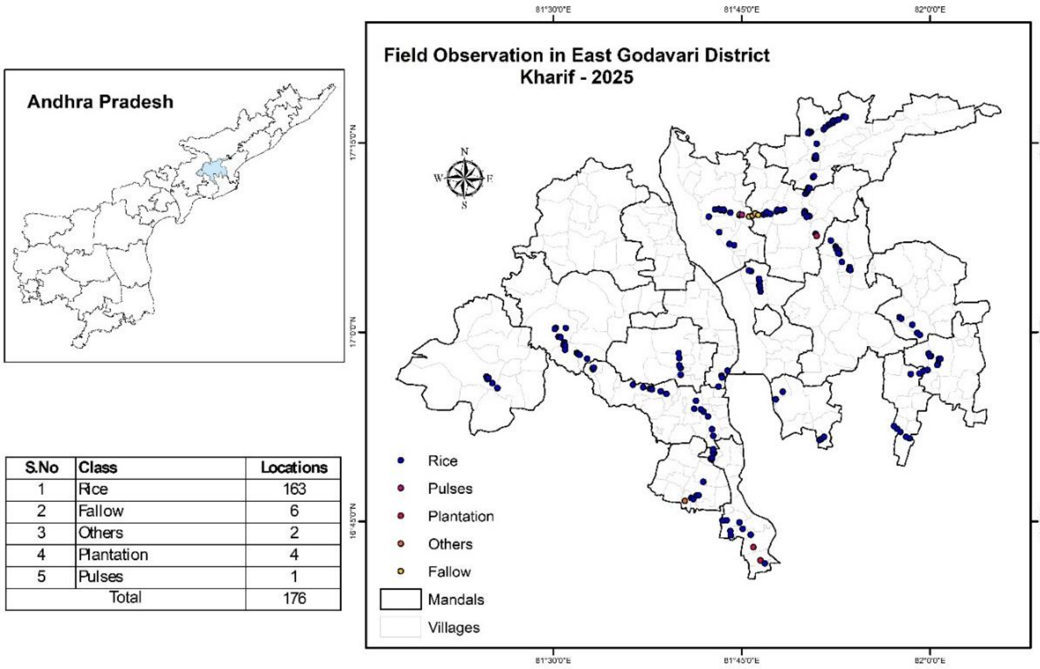
In this study, the Harvest Index (HI) will be determined by estimated biomass through Semi-Physical model for the past years (2022-23, 2023-24 and 2024-25) and yield data obtained from Crop Cutting Experiments (CCEs) for the respective years. Harvest Index will be applied in the estimation of rice crop yield for Kharif 2025-26 in study districts of Andhra Pradesh.

6 Mid-Season Results and Discussion

6.1 Ground truth data for rice crop mapping

ICRISAT team carried out field surveys between 08 and 18 September 2025 to understand the crop during the Kharif season 2025–26 in the study area encompassed five districts namely East Godavari, West Godavari, Eluru, S.P.S Nellore, and Konaseema. These field observations provided the ground signatures required for image classification.

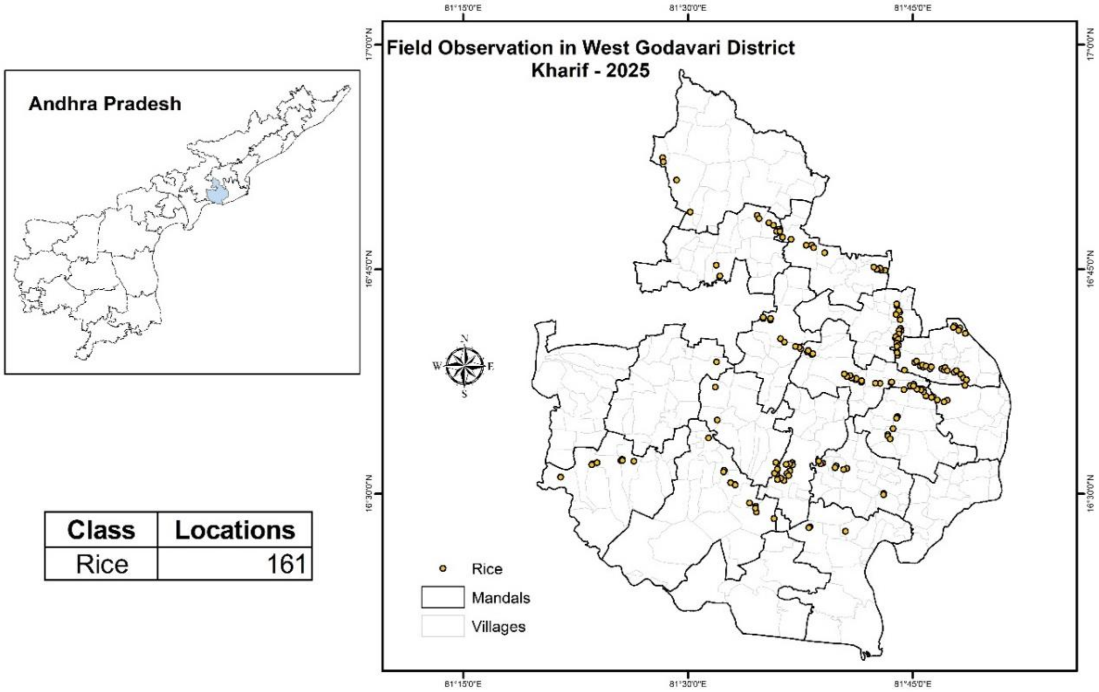
In East Godavari district, a total of 176 ground truth locations were recorded, consisting of 163 rice fields, 6 fallow locations, 2 sites categorized as others, 4 plantation areas, and 1 pulses field. The detailed distribution of these observations will be presented in the corresponding table. Rice is the major food crop cultivated in the district during the Kharif season, and the spatial distribution of polygons representing rice and other crop classes are shown in the respective figure 4.



S.No	Class	Locations
1	Rice	163
2	Fallow	6
3	Others	2
4	Plantation	4
5	Pulses	1
	Total	176

Figure 4: Ground Data of East Godavari District

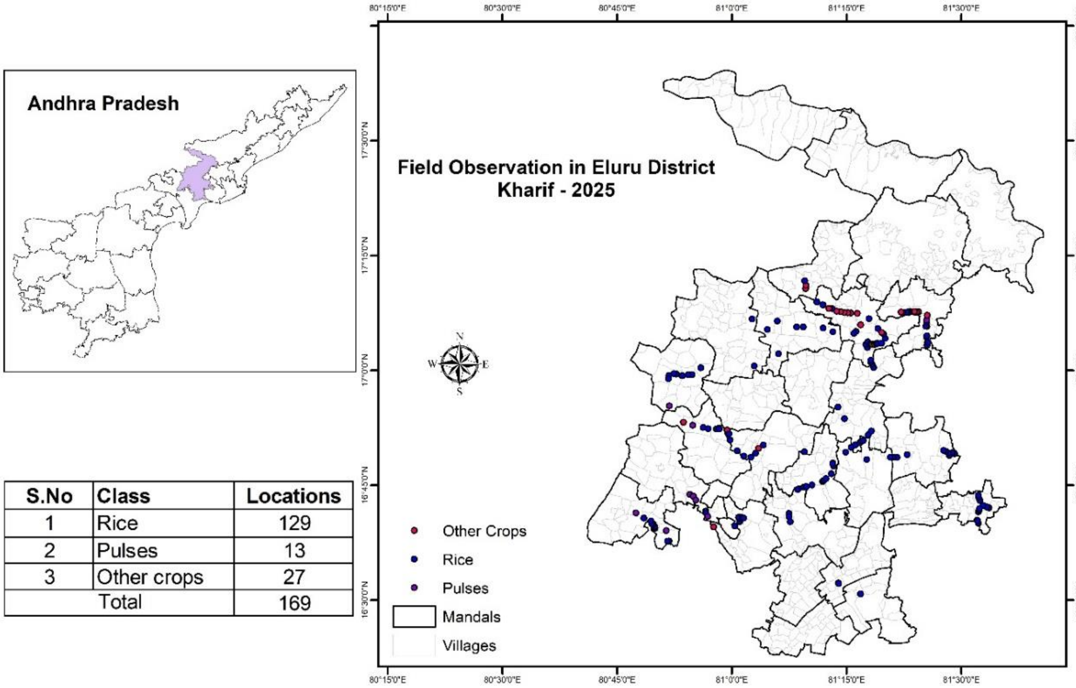
In West Godavari district, the survey documented 161 ground truth locations, all corresponding to rice crop fields. The complete details of these observations will be provided in the respective table. Rice dominates the agricultural landscape of West Godavari during Kharif, and the ground truth polygons for these fields are illustrated in the associated figure 5.



Class	Locations
Rice	161

Figure 5: Ground Data of West Godavari District

In Eluru district, a total of 169 ground truth locations were collected, comprising 129 rice crop fields, 13 pulses locations, and 27 other crop fields. These observations, which reflect the mixed crop pattern of the district, will be summarized in the relevant table. The mapped distribution of polygons for rice and other crops are presented in the corresponding figure 6.

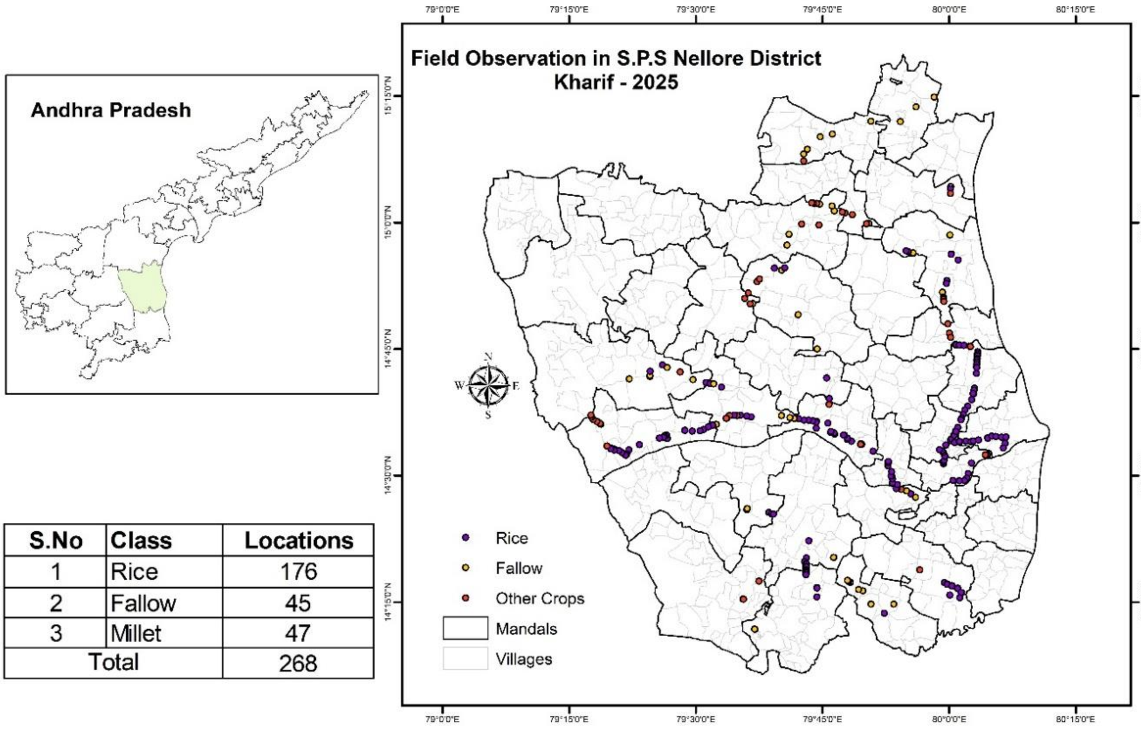


S.No	Class	Locations
1	Rice	129
2	Pulses	13
3	Other crops	27
	Total	169

Figure 6: Ground Data of Eluru District

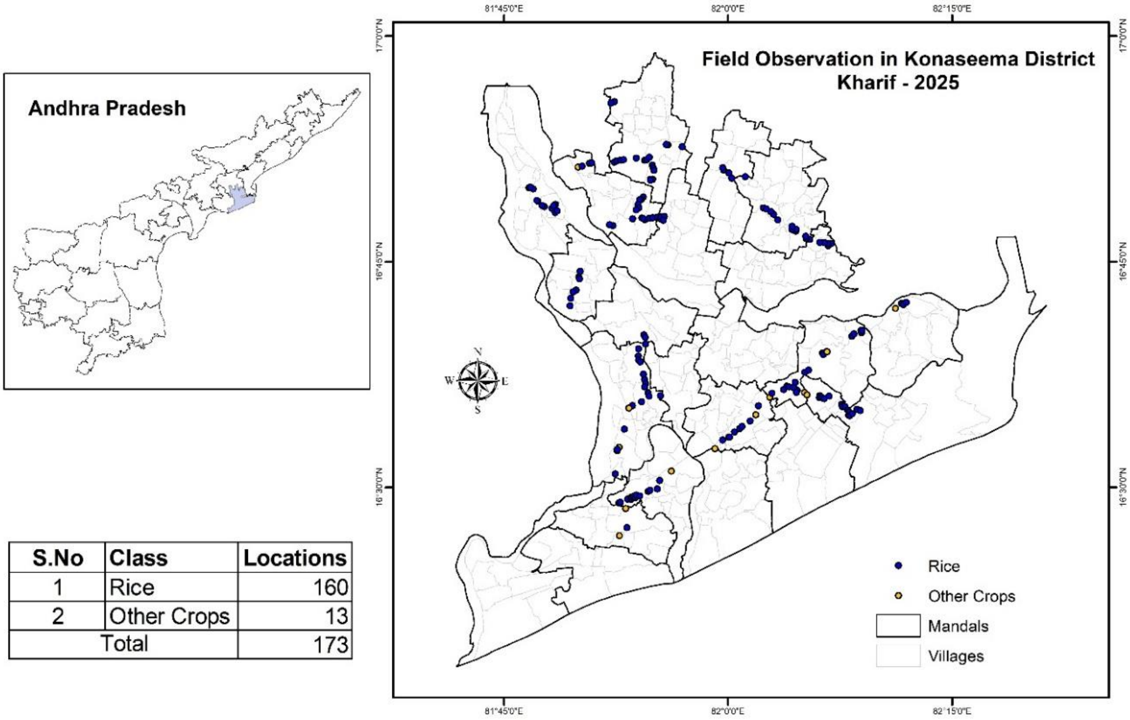
In S.P.S Nellore district, the team captured 268 ground truth locations, including 176 rice fields, 45 fallow areas, and 47 millet fields. The detailed breakdown of these observations will be provided in the associated table. Rice remains the principal Kharif crop here, with millet contributing additional crop diversity. The ground truth polygons representing these classes are mapped and shown in the relevant figure 7.

In Konaseema district, a total of 173 ground truth locations were documented, consisting of 160 rice crop fields and 13 other crop locations. The detailed dataset will be presented in the respective table. Rice is the dominant Kharif crop cultivated in Konaseema, and the mapped polygons categorized by rice and other crop classes are illustrated in the corresponding figure 8.



S.No	Class	Locations
1	Rice	176
2	Fallow	45
3	Millet	47
Total		268

Figure 7: Ground Data of S.P.S Nellore District



S.No	Class	Locations
1	Rice	160
2	Other Crops	13
Total		173

Figure 8: Ground Data of Konaseema District

6.2 Rice crop classification

6.2.1 East Godavari

Rice crop classification for East Godavari was completed using Sentinel-2 imagery supported by 163 rice ground observations. These signatures helped cleanly separate rice from fallow and mixed-crop patches across the district. The classification estimated 79,179 hectares of rice, and the spatial distribution of these mapped rice fields are shown in the corresponding figure 9.

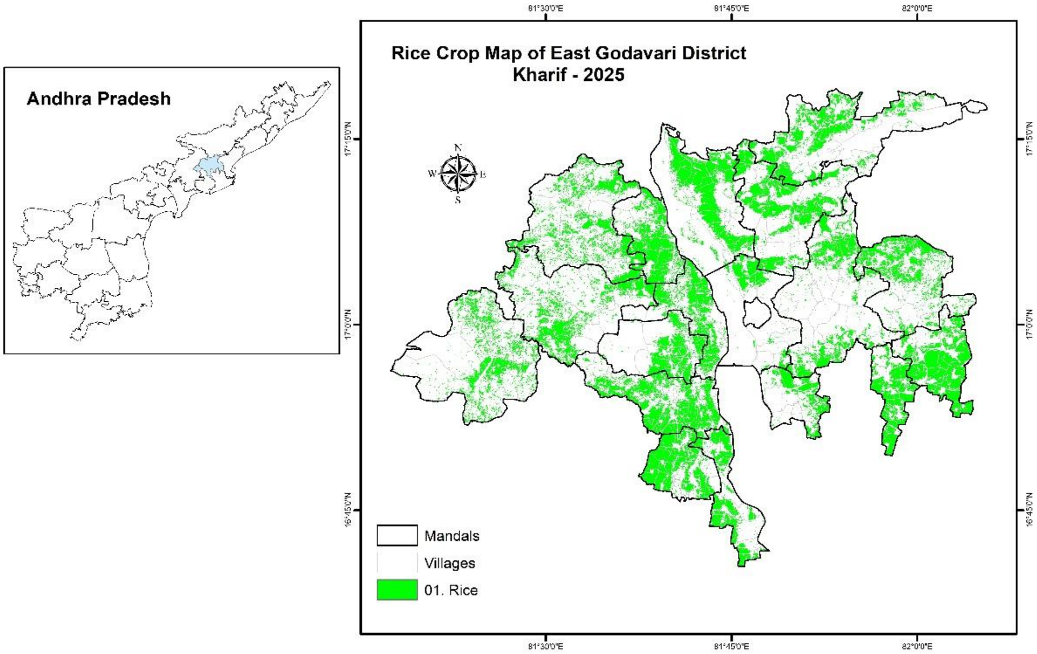


Figure 9: Rice crop map of East Godavari District

6.2.2 West Godavari

In West Godavari, the classification was guided by 161 rice ground truth points. Sentinel-2 clearly captured the crop’s growth stage, making rice extraction straightforward and stable. The classified output indicated about 81,530 hectares of rice in the district, with the mapped extent illustrated in the respective figure 10.

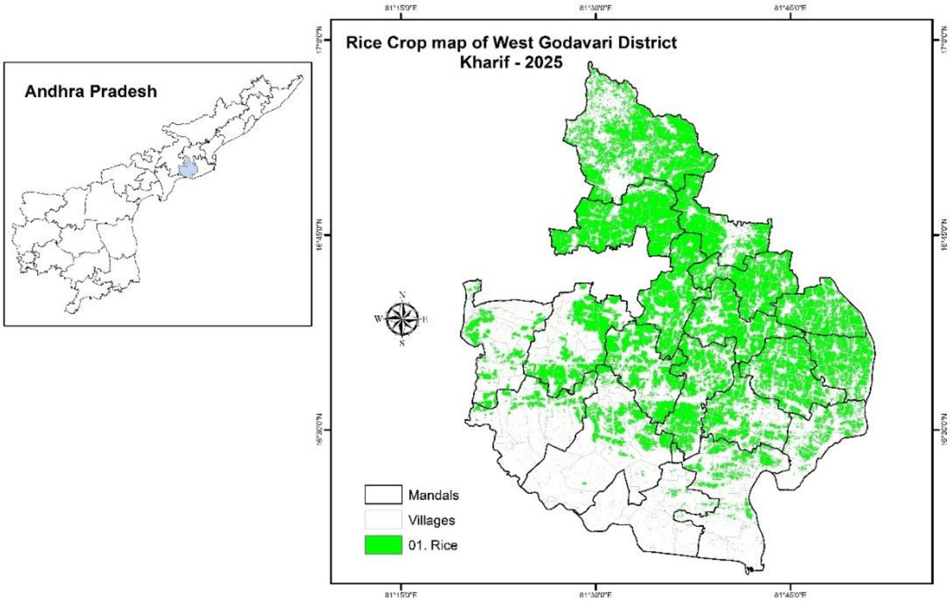


Figure 10: Rice crop map of West Godavari District

6.2.3 Eluru

Rice classification in Eluru relied on 129 reference points collected during fieldwork. The spectral response of rice during the acquisition period allowed for a crisp separation from pulses and other crops. The estimated rice area from the classification came to 88,763 hectares, and the spatial pattern of classified rice fields are shown in the figure 11.

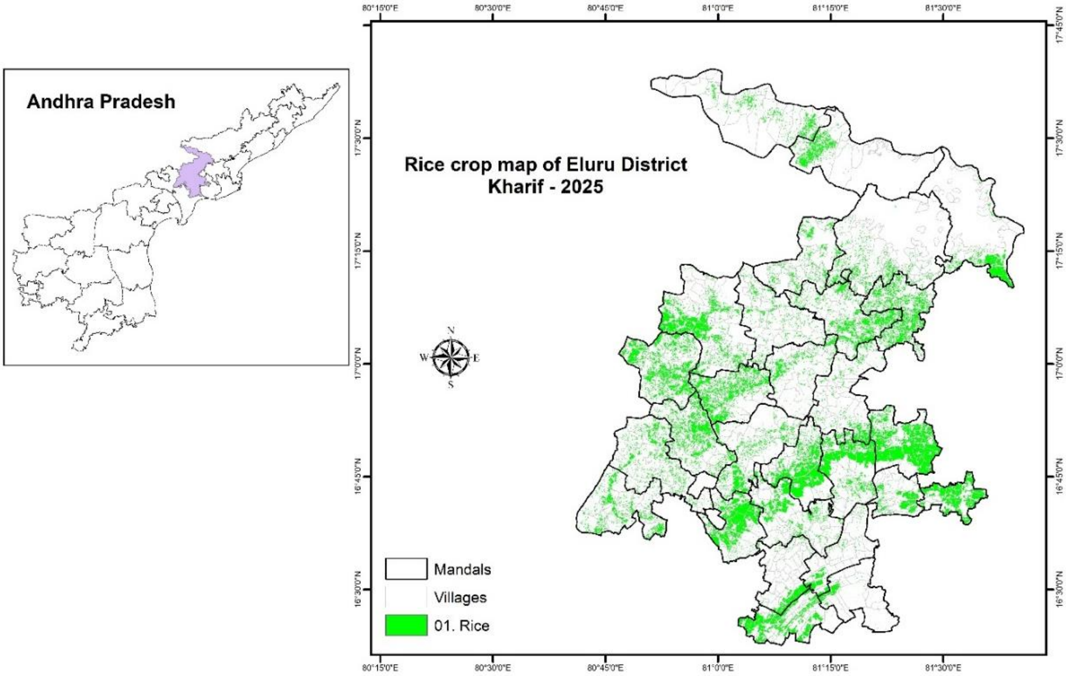


Figure 11: Rice crop map of Eluru District

6.2.4 S.P.S Nellore

For S.P.S Nellore, the classifier used 176 rice observations to build the signatures. Sentinel-2 reflectance during the active crop phase supported a reliable extraction of rice from surrounding fallow and millet fields. The analysis showed a rice area of 1,08,586 hectares, and the mapped distribution are shown in the associated figure 12.

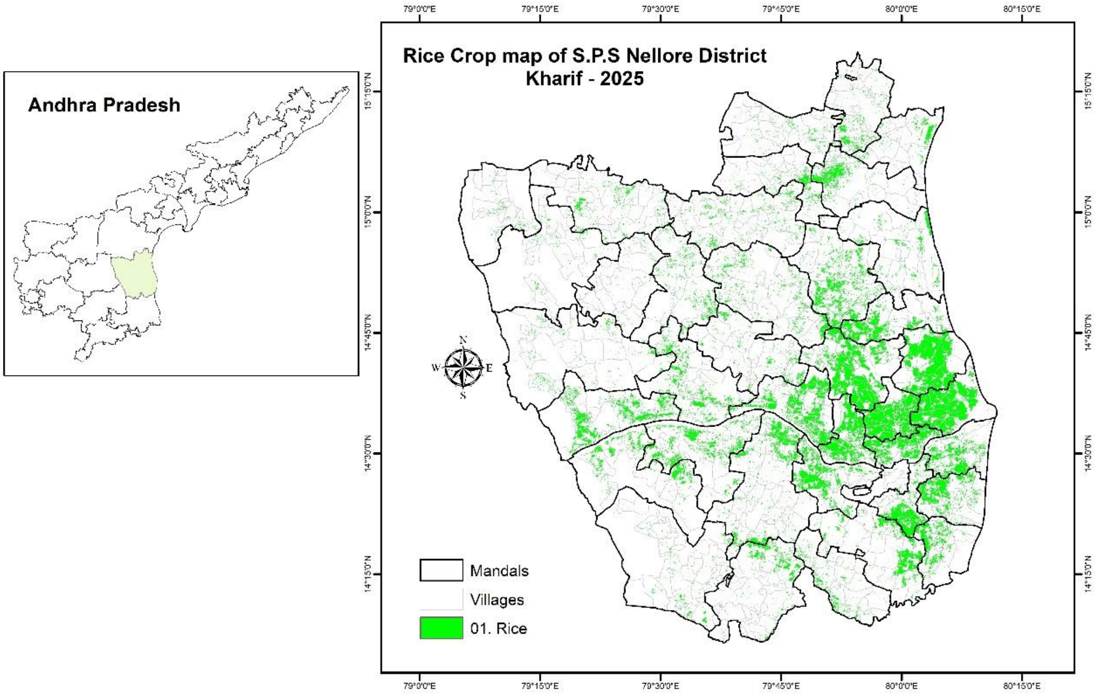


Figure 12: Rice crop map of S.P.S Nellore District

6.2.5 Konaseema

In Konaseema, classification was strengthened by 160 rice ground points, allowing the model to delineate rice accurately across the deltaic landscape. The estimated rice area from the classified output was around 61,837 hectares, and the spatial layout of these rice fields are presented in the relevant figure 13.

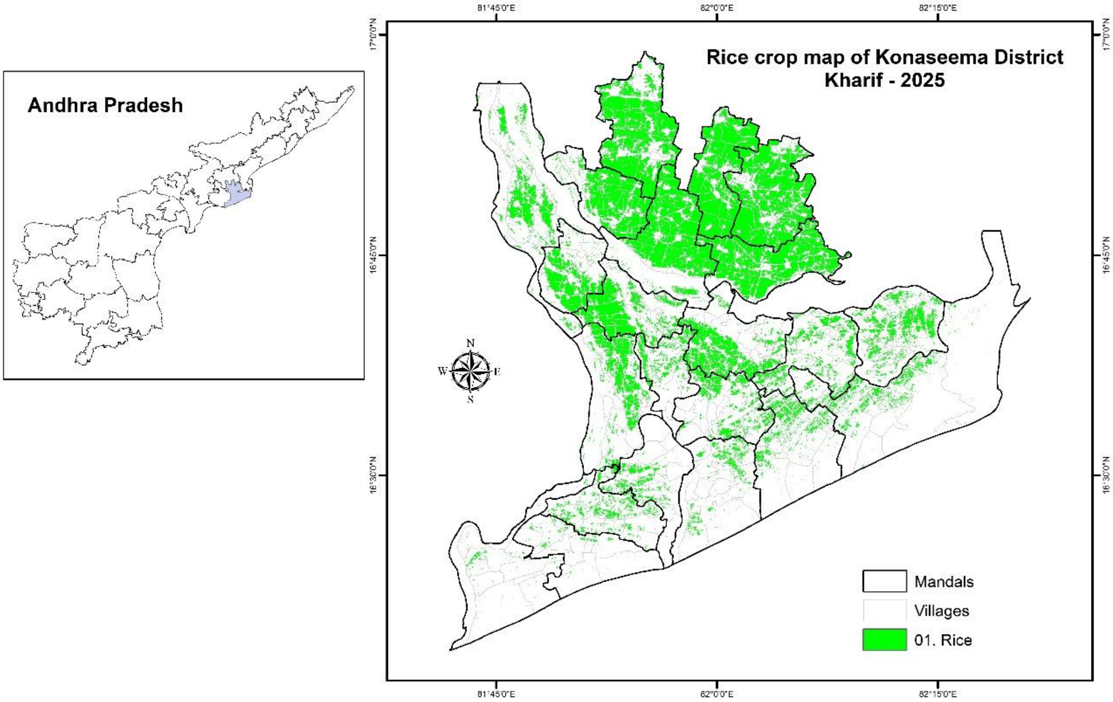


Figure 13: Rice crop map of Konaseema District

6.3 Accuracy assessment of rice crop mapping

6.3.1 East Godavari

In East Godavari, the accuracy assessment was based on 313 validation points. Rice showed strong consistency with a user's accuracy of 97.99%, while the other-class category achieved 89.63%. The district's overall accuracy reached 93.93%, indicating reliable agreement between ground observations and the classified output.

Table 3: Error matrix of classification of East Godavari

Class	Rice	Other class	Total	User's Accuracy
Rice	146	3	149	97.99%
Other class	17	147	164	89.63%
Total	163	150	313	
	89.57	98	**Overall Accuracy**	93.93

6.3.2 Eluru

In Eluru, the evaluation used 248 validation points. Rice recorded a user's accuracy of 91.53%, and the other-class category stood at 83.85%. The overall accuracy of 87.9% reflects reasonable classification performance, with some confusion between rice and other classes.

Table 4: Error matrix of classification of Eluru

Class	Rice	Other Class	Total	User's Accuracy
Rice	108	10	118	91.53%
Other class	21	109	130	83.85%
Total	129	119	248	
	83.07	91.6	**Overall Accuracy**	87.9

6.3.3 Konaseema

In Konaseema, the classifier was tested against 312 validation points and delivered excellent performance. Rice achieved a user's accuracy of 99.34%, while the other-crop class reached 93.17%. The overall accuracy was 96.15%, demonstrating strong separation between crop classes.

Table 5: Error matrix of classification of Konaseema

Class	Rice	Other Crop	Total	User's Accuracy
Rice	150	1	151	99.34%
Other class	11	150	161	93.17%
Total	161	151	312	
	93.17	99.34	**Overall Accuracy**	96.15

6.3.4 S.P.S Nellore

In S.P.S Nellore, the accuracy assessment used 350 validation points. Rice showed a user's accuracy of 86.71%, and the other-class category was close behind at 84.75%. The overall accuracy of 85.71% suggests more spectral overlap across classes in this district than in the coastal ones.

Table 6: Error matrix of classification of S.P.S Nellore

Class	Rice	Other Class	Total	User's Accuracy
Rice	150	23	173	86.71%
Other class	27	150	177	84.75%
Total	177	173	350	
	84.75	86.71	**Overall Accuracy**	85.71

6.3.5 West Godavari

In West Godavari, the classification was evaluated using 316 validation points. Rice achieved 100% user's accuracy, and the other-class category reached 94.44%. The overall accuracy of 97.47% marks this as the highest-performing district in the assessment.

Table 7: Error matrix of classification of West Godavari

Class	Rice	Other Class	Total	User's Accuracy
Rice	154	0	154	100.00%
Other class	9	153	162	94.44%
Total	163	153	316	
	94.44	100	**Overall Accuracy**	97.47

6.4 Crop Condition Assessment

The fortnightly rice crop condition was observed throughout the crop duration (July to September) at village level (Figure 14 to 18). During July, rice fields across all districts moved through their early establishment and vegetative stages, starting with light green, partially settled seedlings in early July and progressing into a more uniform, deeper green canopy by the end of the month. Early August showed strong, healthy tillering and stable growth supported by consistent irrigation, but conditions shifted sharply in the second half of August, when all districts experienced significant crop stress triggered by uneven rainfall, short dry spells, and local water-management issues; this stress was clearly visible in the NDVI change captured in satellite imagery. With improved rainfall in early September, most fields recovered quickly, returning to high chlorophyll activity as the crop moved into panicle initiation and early heading. By late September, rice had advanced into heading and early grain filling, canopy greenness began to level off, and fields showed steady maturation with no lingering district-wide stress from the August event.

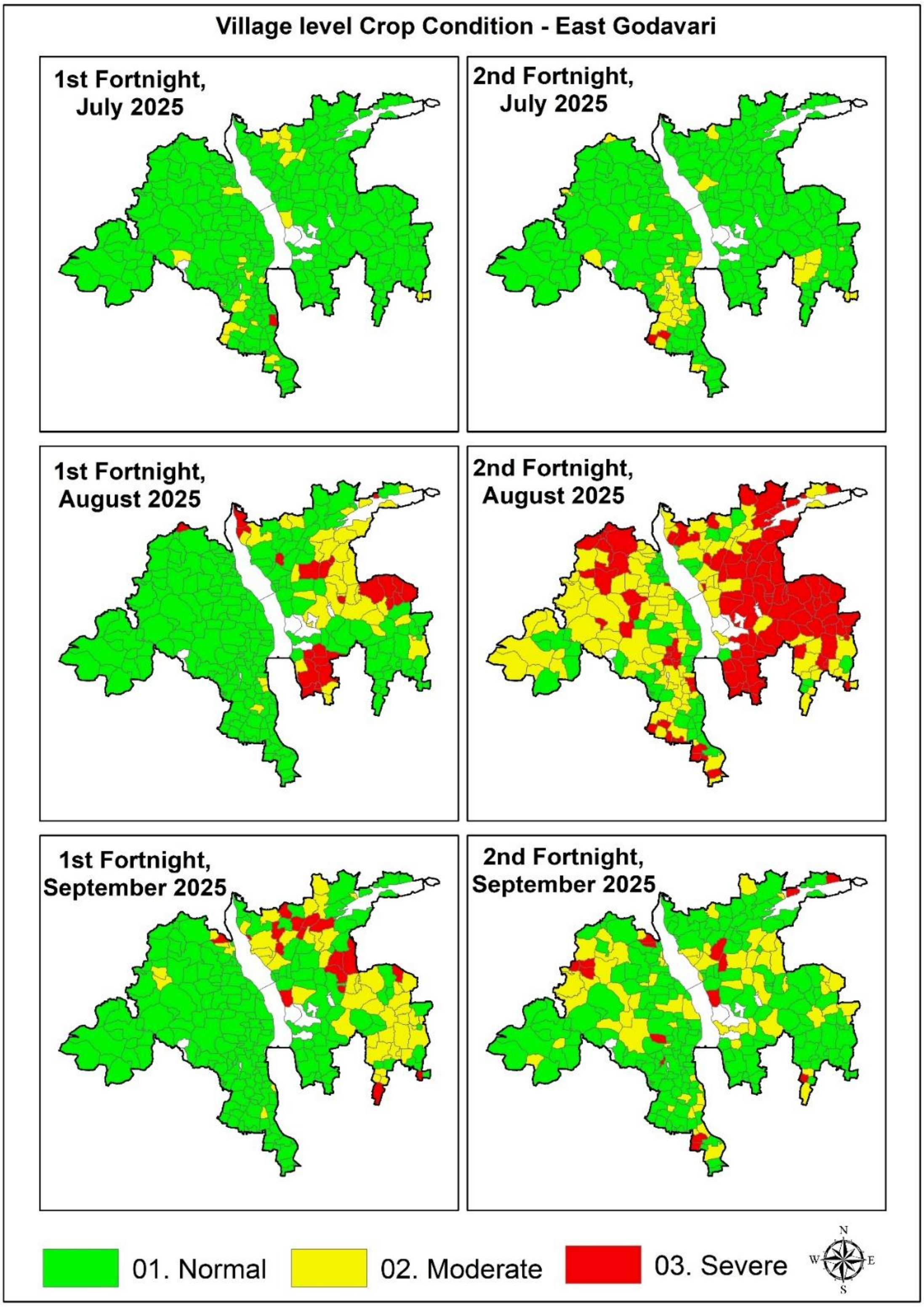


Figure 14: Rice crop stress maps of East Godavari District

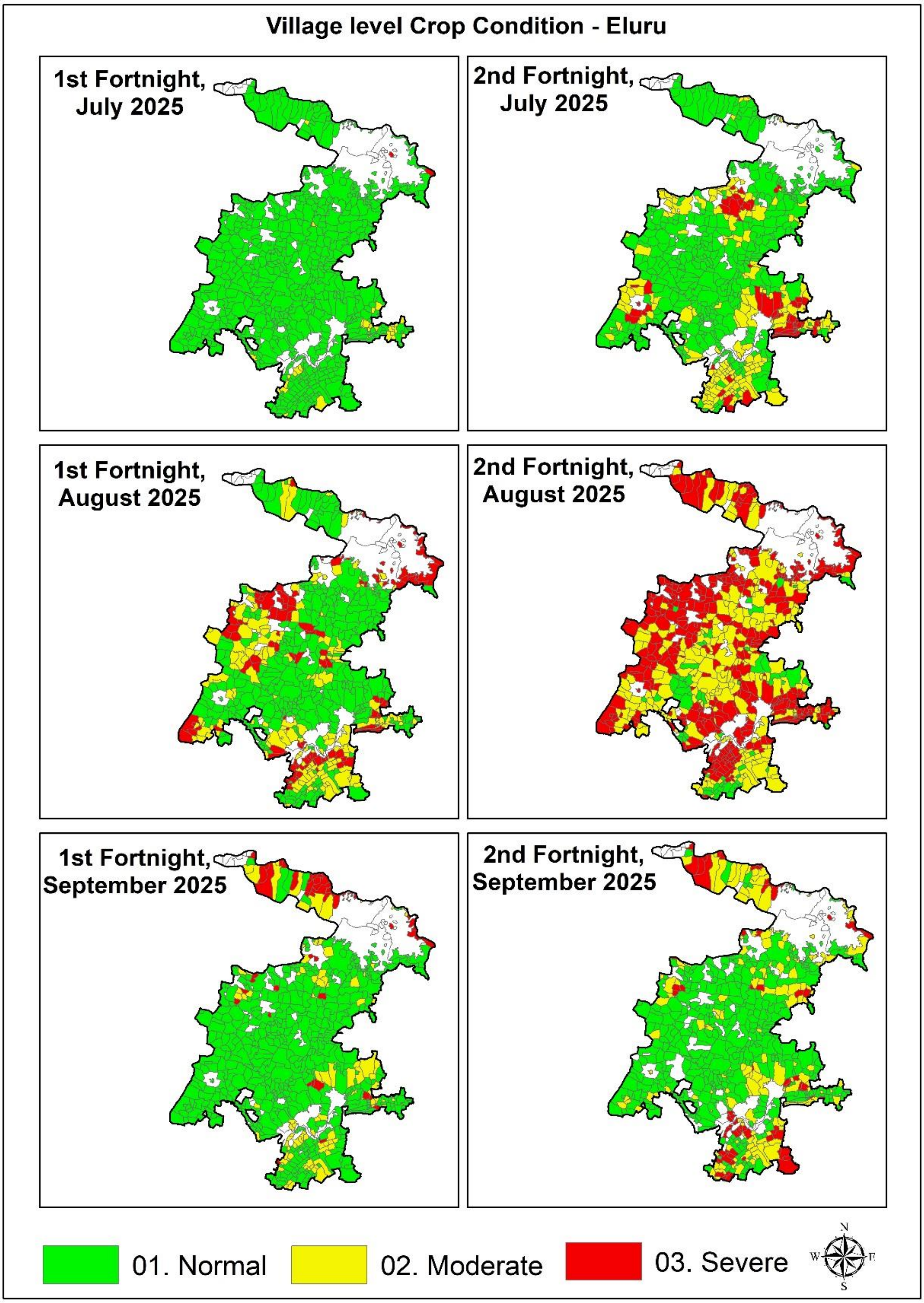


Figure 15: Rice crop stress maps of Eluru District

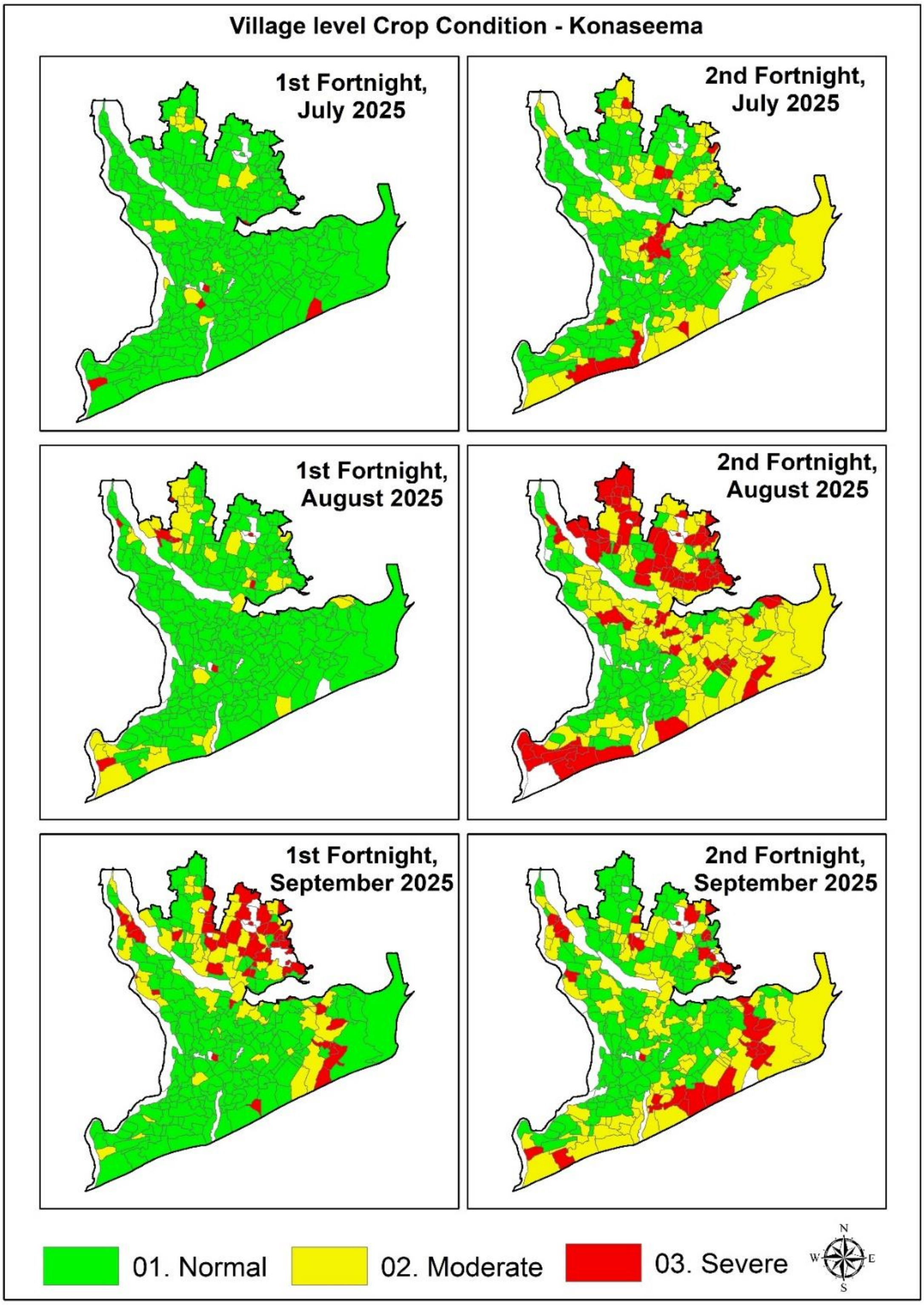


Figure 16: Rice crop stress maps of Konaseema District

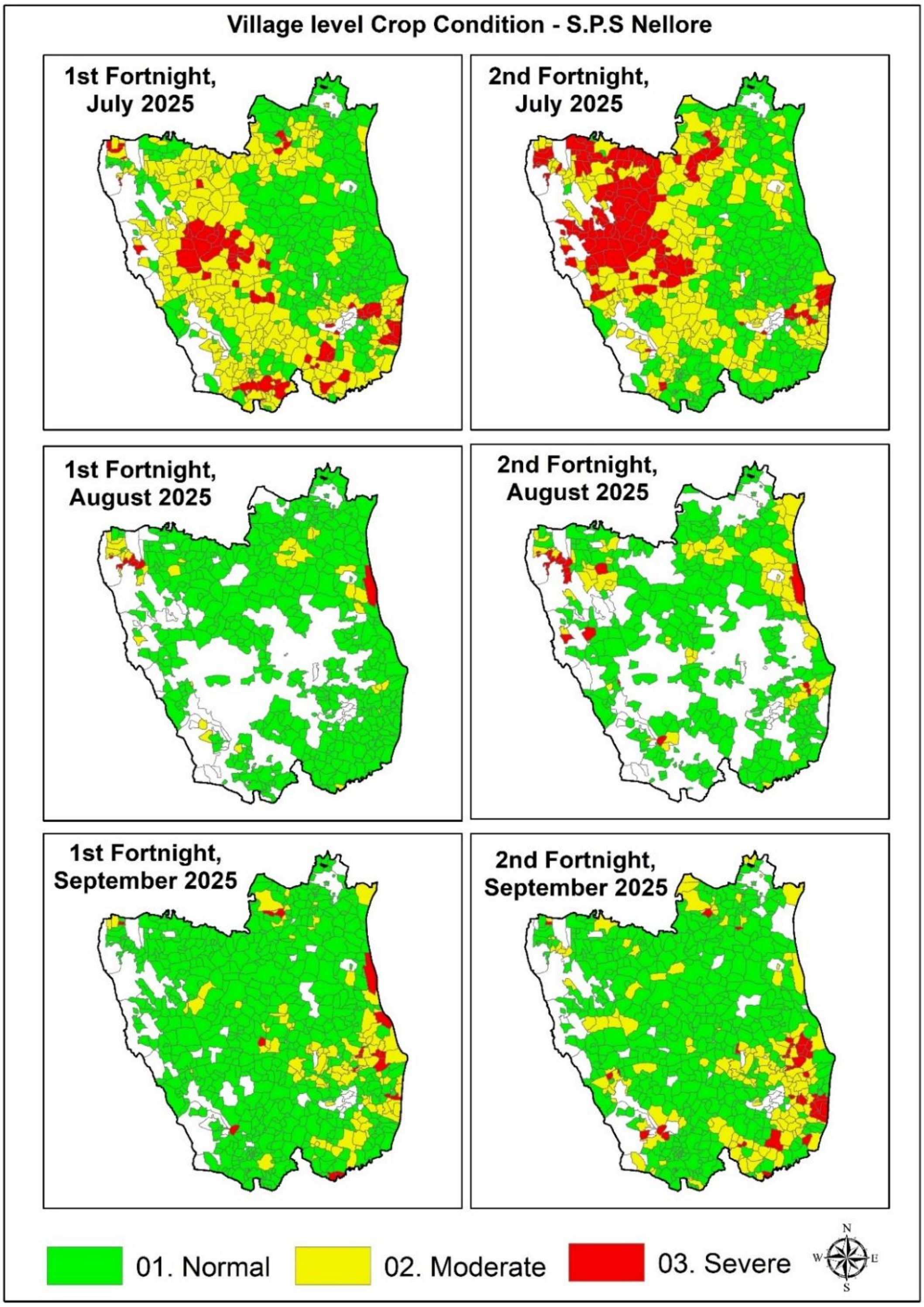


Figure 17: Rice crop stress maps of S.P.S Nellore District

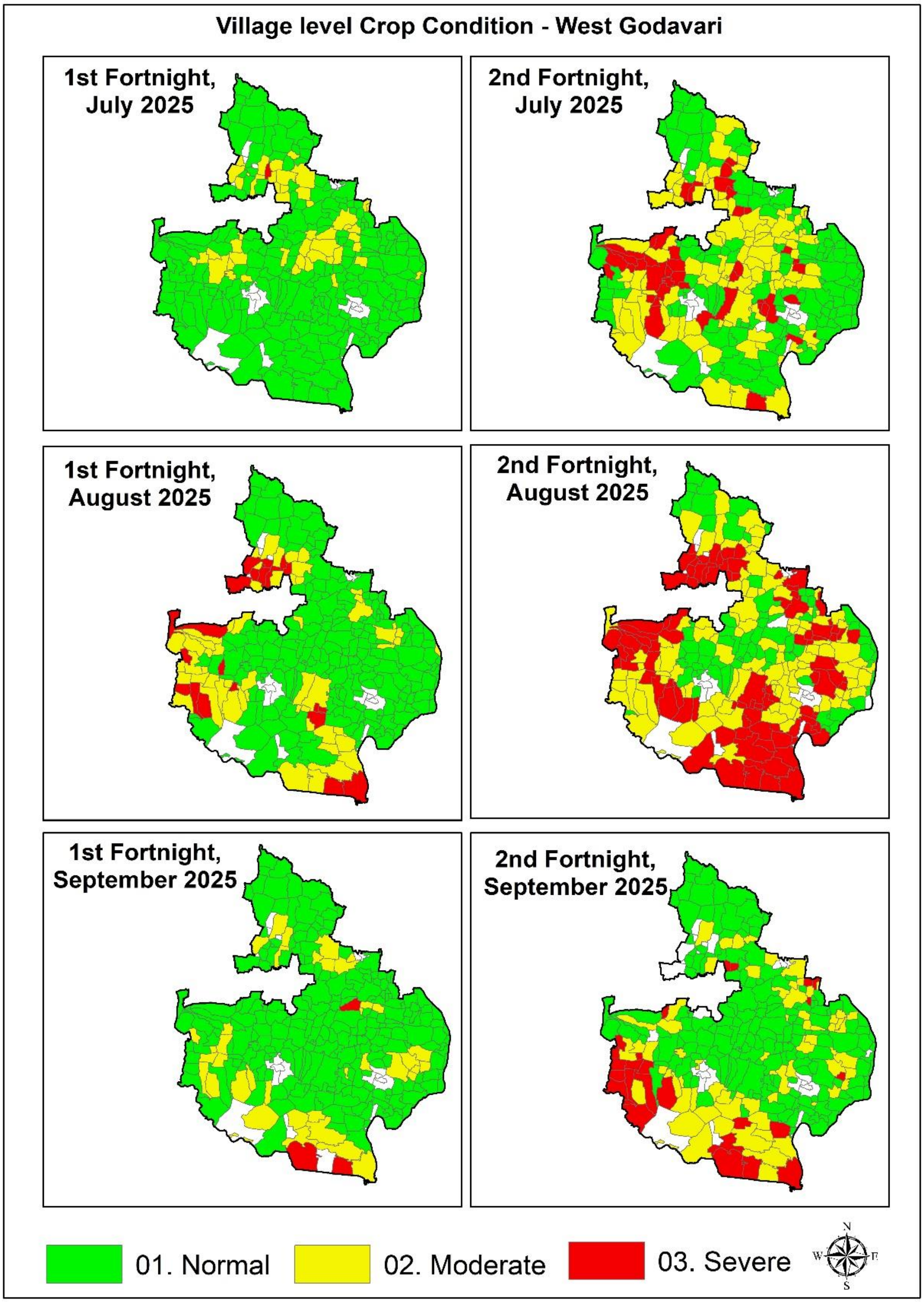


Figure 18: Rice crop stress maps of West Godavari District

6.5 Planting date

The planting date of rice crop was identified through satellite data. The sowing indicators show that East Godavari completed most of its rice transplanting between Julian 193 and 201 (mid to late July) (Figure 19). Around 29,936 ha showed active sowing signals at Julian 193, followed by 27,474 ha at Julian 201, indicating that the bulk of fields were transplanted within this window. By Julian 209, only 10,158 ha still carried new-transplant signatures, confirming that sowing had largely concluded.

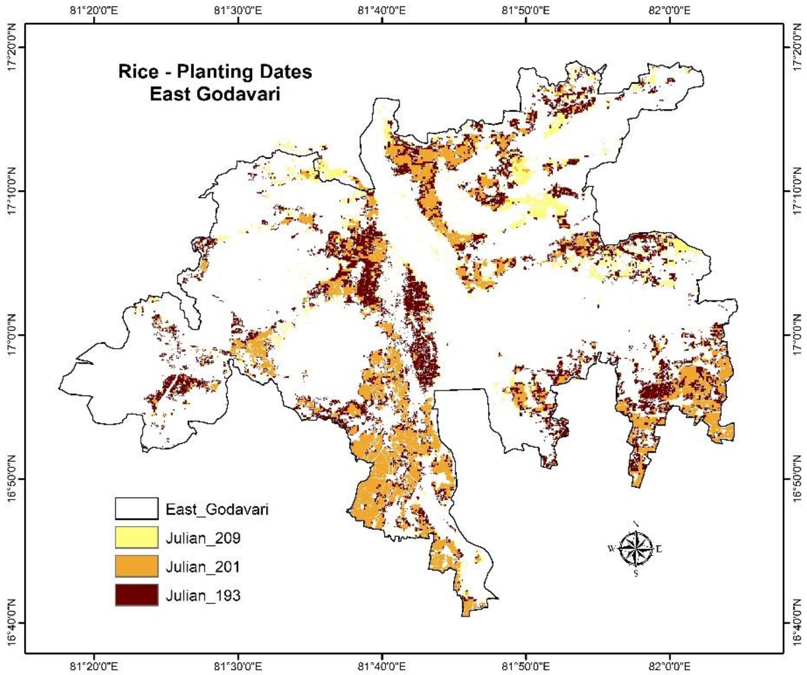


Figure 19: Rice planting dates of East Godavari District

In Eluru, sowing activity followed a similar pattern, concentrated in mid–late July (Figure 20). The district showed 26,627 ha actively sown at Julian 193 and 27,775 ha at Julian 201, reflecting a consistent transplanting timeline. By Julian 209, the area showing sowing characteristics reduced to 21,264 ha, marking the shift from transplanting to early vegetative growth.

Konaseema showed a slightly wider sowing window (Figure 21). Early activity around Julian 193 accounted for 15,653 ha, followed by a peak of 28,618 ha at Julian 201, showing that late July was the main transplanting phase. By Julian 209, the sowing-stage area reduced to 12,172 ha, indicating that most fields had moved past the initial establishment stage.

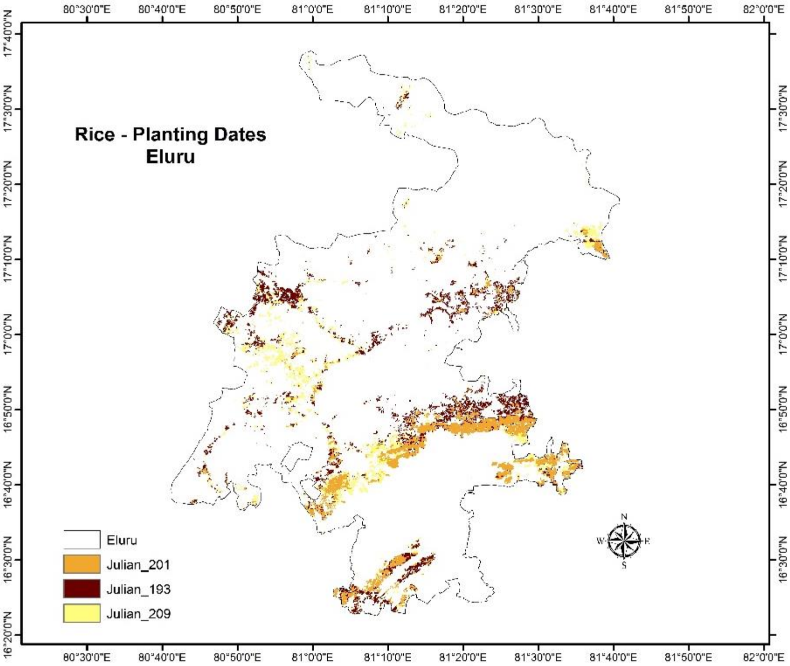


Figure 20: Rice planting dates of Eluru District

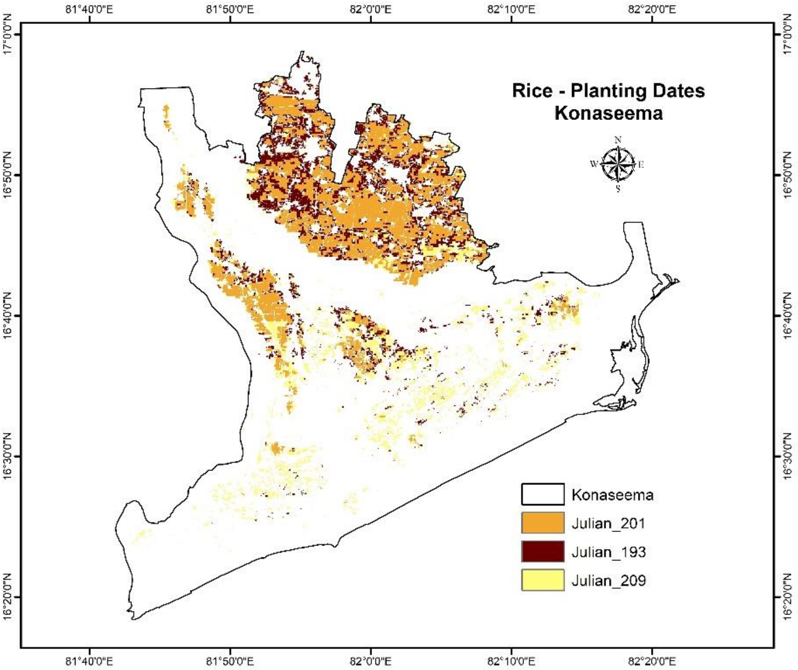


Figure 21: Rice planting dates of Konaseema District

In West Godavari, sowing was more staggered (Figure 22). The district recorded 45,557 ha showing sowing activity at Julian 201, but earlier signals around Julian 193 were smaller (8,034 ha). By Julian 209, sowing-stage extent increased again to 23,975 ha, reflecting variability across command and non-command irrigation zones and confirming a broader transplanting period from mid-July into early August.

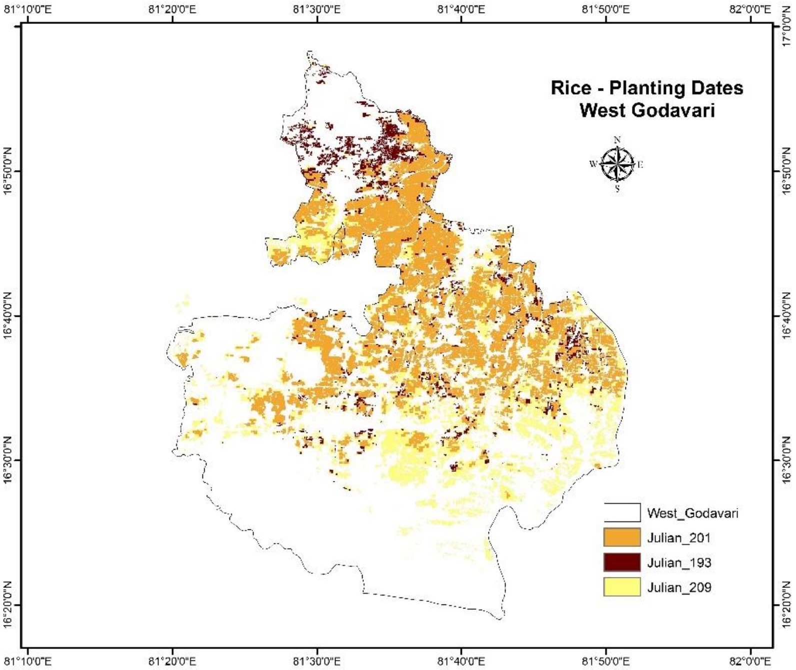


Figure 22: Rice planting dates of West Godavari District

S.P.S Nellore showed the earliest sowing pattern among all districts (Figure 22). Activity began as early as Julian 129 with 31,803 ha, continued through Julian 137 with 10,673 ha, and expanded during Julian 145 with 28,657 ha. By Julian 153, another 14,279 ha showed transplant signatures. These dates correspond to early June through mid-July, consistent with Nellore's long-established practice of advancing Kharif rice sowing ahead of monsoon onset.

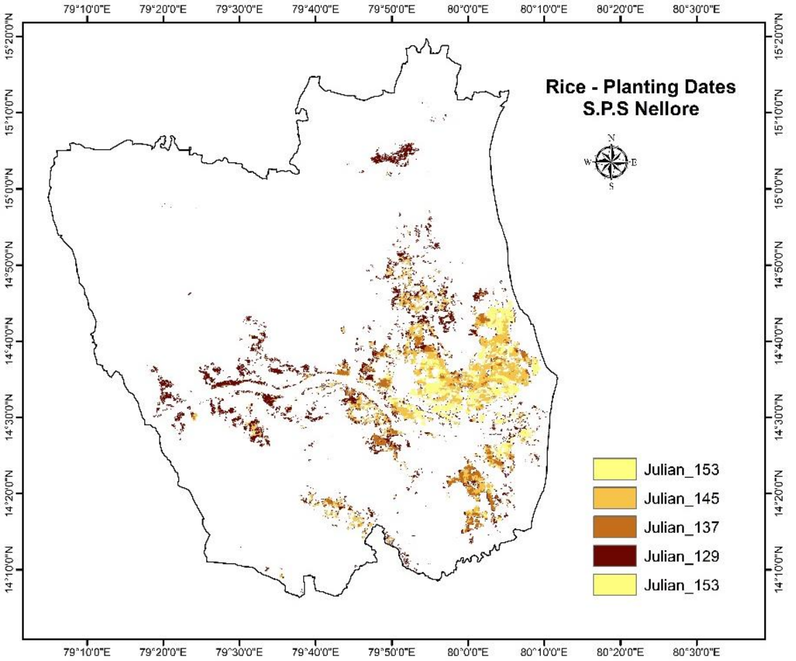


Figure 23: Rice planting dates of S.P.S Nellore District

7 Conclusion

The MSR reporting for the study districts provided a clear picture of rice distribution, crop condition, and planting dates for Kharif 2025–26. The satellite-based classification showed strong consistency with on-ground cropping patterns across all districts, capturing both the spatial extent of rice and the transitions through early-season growth stages.

VCI analysis indicated that rice maintained healthy vegetation conditions from July 1st FN through August 1st FN in every district. A clear stress signal emerged during August 2nd FN, affecting all regions simultaneously and reflecting short-term moisture constraints. Conditions recovered by September 1st FN, with vegetation returning to stable growth levels as the crop moved toward its reproductive phase.

Planting-date information derived from Sentinel-2 revealed distinct sowing windows across the districts. East Godavari, Eluru, and Konaseema carried out most of their transplanting between mid-July and early August, with the final week of July marking the main peak. West Godavari showed a broader and more staggered planting window extending into early August, consistent with its irrigation patterns and field-preparation variability. S.P.S. Nellore followed an earlier schedule altogether, beginning sowing in early June and continuing through mid-July, aligning with its long-standing early Kharif cultivation practices.

8 Expected Results

The expected results of the study during Kharif 2025-26 are.

(i) Rice crop map of East Godavari, Eluru, Konaseema, West Godavari, and S.P.S. Nellore districts (pixel wise) and acreage. **(Completed)**

(ii) Planting date map **(Completed)**

(iii) Village wise Rice crop yield. (IU wise)-**To be completed.**

9 Schedule

The project schedule is outlined in Table 2.

Table 8: Project schedule

Activity	1FN-June	2FN-June	1FN-July	2FN-July	1FN-Aug	2FN-Aug	1FN-Sep	2FN-Sep	1FN-Oct	2FN-Oct	1FN-Nov	2FN-Nov	1FN-Dec	2FN-Dec
Ground Truth data Collection						☑	☑							
Rice crop map generation								☑	☑					
Crop Condition Assessment			☑	☑	☑	☑	☑	☑	☑	☑	☑	☑		
Planting date map generation									☑	☑				
Input data preparation for SPM		☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑		
CCE data Collection												☑	☑	
Yield estimation and Validation													☑	☑
Mid Season Report										☑	☑			
End Season Report													☑	☑

10 Related Papers

[1], [2], [3], [4], [5], [6], [7], [8], [9], [10], [11], [12], [13], [14], [15], [16]

11 References

- Ali, A.M., Savin, I., Poddubskiy, A., Abouelghar, M., Saleh, N., Abutaleb, K., ElShirbeny, M., Dokukin, P. "Integrated method for rice cultivation monitoring using Sentinel-2 data and Leaf Area Index." Egyptian Journal of Remote Sensing and Space Science 24, no. 3 (2021): 431–441. https://doi.org/10.1016/j.ejrs.2020.06.007.
- Cai, Y., Lin, H., Zhang, M. "Mapping paddy rice by the object-based random forest method using time series Sentinel-1/Sentinel-2 data." Adv. Space Res. 64 (2019): 2233-2244.

- Dwivedi, M., Saxena, S., Ray, S.S. "Assessment of rice biomass production and yield using semi-physical approach and remotely sensed data." Int. Arch. Photogramm. Remote Sens. Spat. Inf. Sci. 42 (2019): 217–222.

- Gumma, M.K., Thenkabail, P.S., Panjala, P., Teluguntla, P., Yamano, T. and Mohammed, I., 2022. Multiple agricultural cropland products of South Asia developed using Landsat-8 30 m and MODIS 250 m data using machine learning on the Google Earth Engine (GEE) cloud and spectral matching techniques (SMTs) in support of food and water security. GIScience & Remote Sensing, 59(1), pp.1048-1077.
- Gumma, M.K., Tummala, K., Dixit, S., Collivignarelli, F., Holecz, F., Kolli, R.N. and Whitbread, A.M., 2022. Crop type identification and spatial mapping using Sentinel-2 satellite data with focus on field-level information. Geocarto International, 37(7), pp.1833-1849.
- Gumma, M.K., Kadiyala, M.D.M., Panjala, P., Ray, S.S., Akuraju, V.R., Dubey, S., Smith, A.P., Das, R. and Whitbread, A.M., 2022. Assimilation of remote sensing data into crop growth model for yield estimation: A case study from India. Journal of the Indian Society of Remote Sensing, 50(2), pp.257-270.
- Nihar, A., Patel, N.R., Singh, R. et al. "Satellite-Based Light Use Efficiency Model for Sugarcane Yield Estimation at Field Scale." J Indian Soc Remote Sens 51 (2023): 1357–1369. https://doi.org/10.1007/s12524-023-01712-1.
- Pazhanivelan, S., Geethalakshmi, V., Tamilmounika, R., Sudarmanian, N.S., Kaliaperumal, R., Ramalingam, K., Sivamurugan, A.P., Mrunalini, K., Yadav, M.K., Quicho, E.D. "Spatial Rice Yield Estimation Using Multiple Linear Regression Analysis, Semi-Physical Approach and Assimilating SAR Satellite Derived Products with DSSAT Crop Simulation Model." Agronomy 12, no. 9 (2022): 2008. https://doi.org/10.3390/ agronomy12092008.
- Singha, M., Dong, J., Sarmah, S., You, N., Zhou, Y., Zhang, G., Doughty, R., Xiao, X. "Identifying floods and flood-affected paddy rice fields in Bangladesh based on Sentinel-1 imagery and Google Earth Engine." ISPRS-J. Photogramm. Remote Sens. 166 (2020): 278-293.
- Tripathy, Rojalin, Chaudhary, K., Nigam, Rahul, R., Manjunath, R., Shibendu, Ray, J., Parihar, J. "Operational semi-physical spectral-spatial wheat yield model development." ISPRS - International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences XL-8 (2014): 977-981.
- Tripathy, Rojalin, Chaudhari, K. N., Bairagi, G. D. Pal, Om, Das, Rajesh, Bhattacharya, B. K. "Towards Fine-Scale Yield Prediction of Three Major Crops of India Using Data from Multiple Satellite." Journal of the Indian Society of Remote Sensing 50 (2022): 271-284.

- Xu, J., Yang, J., Xiong, X., Li, H., Huang, J., Ting, K.C., Ying, Y., Lin, T. "Towards interpreting multi-temporal deep learning models in crop mapping." Remote Sens. Environ. 264 (2021): Article 112599.
- Yang, H., Pan, B., Li, N., Wang, W., Zhang, J., Zhang, X. "A systematic method for spatio-temporal phenology estimation of paddy rice using time series Sentinel-1 images." Remote Sens. Environ. 259 (2021): Article 112394.
- YES-Tech manual for implementation of yield estimation based on technology (2023). https://pmfby.gov.in/pdf/YES_TECH_Manual_2023.pdf.
- Yin, Q., Liu, M., Cheng, J., Ke, Y., Chen, X. "Mapping paddy rice planting area in northeastern China using spatiotemporal data fusion and phenology-based method." Remote Sens. 11, no. 14 (2019): 1699.
- Zhang, Z., Liu, Q., Wang, Y. "Road extraction by deep residual u-net." IEEE Geosci. Remote Sens. Lett. 15, no. 5 (2018): 749-753.
- Protocol of smart sampling for crop cutting experiments. 2019. Department of Agriculture, Coop. & Farmers' Welfare, Ministry of Agriculture & Farmers' Welfare, Government of India, New Delhi – 110001, September, 2019. (NRSC-RSAA-ASAG-AGSciOff-March 2019-TR0001259-v1.0).

*****

1. Gumma, M.K., et al., *Geospatial analysis to identify millet suitable areas in the upland rice ecosystem of Odisha.* Journal of Agriculture and Food Research, 2025. **19**: p. 101593.
2. Bellam, P.K., et al., *Soil Organic Carbon Mapping Using Multi-Frequency SAR Data and Machine Learning Algorithms.* Land, 2025. **14**(11): p. 2105.
3. Nukala, R.M., et al., *Strategic Ground Data Planning for Efficient Crop Classification Using Remote Sensing and Mobile-Based Survey Tools.* Geographies, 2025. **5**(4): p. 59.
4. Panjala, P., M.K. Gumma, and S. Mesapam, *Assessing public health risks from crop residue burning: a spatiotemporal case study in Telangana, India.* Air Quality, Atmosphere & Health, 2025. **18**(10): p. 3105-3115.
5. Gajjala, S., et al., *Rice Yield Assessment in Nalgonda: A Comparative Study of APSIM and Semi-Physical Models with Remote Sensing Integration.* Journal of Scientific Research and Reports, 2025. **31**(9): p. 371-384.
6. Panjala, P., M.K. Gumma, and S. Mesapam, *Satellite-Based Monitoring of Crop Intensity Changes in Kaleshwaram Lift Irrigation Command Area.* Sustainable Geosciences: People, Planet and Prosperity, 2025: p. 100003.
7. Panjala, P., et al., *Geospatial Analysis of Crop Residue Burn Areas and Their Dates for Emission Mitigation Strategies.* Sustainability, 2025. **17**(6): p. 2508.
8. Gumma, M.K., P. Panjala, and P. Teluguntla, *Mapping heterogeneous land use/land cover and crop types in Senegal using sentinel-2 data and machine learning algorithms.* International Journal of Digital Earth, 2024. **17**(1).
9. Bellam, P.K., et al. *Soil Organic Carbon Mapping Using Sentinel-1 And ALOS-2 SAR Data*. in *2024 IEEE India Geoscience and Remote Sensing Symposium (InGARSS)*. 2024. IEEE.
10. Teluguntla, P., et al. *Landsat-derived global rainfed and irrigated area product@ 30m (LGRIP30): A study of irrigated and rainfed areas at the country, state, and county level for conterminous United States (CONUS)*. in *AGU Fall Meeting Abstracts*. 2024.
11. Teluguntla, P., et al., *Global Food Security Support Analysis Data (GFSAD) Using Remote Sensing in Support of Food and Water Security in the 21st Century: Current Achievements and Future Possibilities*, in *Remote Sensing Handbook, Volume III*. 2024, CRC Press. p. 187-228.

12. Gumma, M.K., et al., *Real Time Monitoring of Cropping Pattern Using Geospatial Analysis.* 2024.
13. Panjala, P., M.K. Gumma, and S. Mesapam, *Geospatial assessment of cropping pattern shifts and their impact on water demand in the Kaleshwaram lift irrigation project command area, Telangana.* Frontiers in Remote Sensing, 2024. **5**: p. 1451594.
14. Gumma, M.K., et al., *Spatial distribution of cropping systems in South Asia using time-series satellite data enriched with ground data.* Remote Sensing, 2024. **16**(15): p. 2733.
15. Gumma, M.K., et al., *Optimizing crop yield estimation through geospatial technology: a comparative analysis of a semi-physical model, crop simulation, and machine learning algorithms.* AgriEngineering, 2024. **6**(1): p. 786-802.
16. Mandapati, R., et al., *Field-level rice yield estimations under different farm practices using the crop simulation model for better yield.* Plant Science Today, 2024. **11**(1): p. 234-240.