Project report
November 2019 – June 2020

Remote Sensing for Agriculture Resilience (R-SAR) – India Chapter

Submitted to
Swiss Agency for Development and Cooperation (SDC)
New Delhi

September 2020

ICRISAT DEVELOPMENT CENTER

INTERNATIONAL CROPS RESEARCH INSTITUTE FOR THE SEMI-ARID TROPICS

Contents

Project overview

The project aims at increasing the adoption of insurance solutions and risk management measures by India's smallholder farmers for increased resilience to climate-related risks through the use of advanced remote sensing technology and science-led advisories through collective action.

The additional component of the India chapter would contribute to the following three of the four outcomes of RIICE III:

1. Smallholder farmers are covered by RIICE supported climate risk mitigation and transfer solutions
(Ind: number of smallholder farmers covered by RIICE-supported climate risk resilience and insurance solutions (gender-disaggregated); No. of states that recognize farmer collectives as appropriate institutions for small farmers' agriculture risk resilience)

2. Institutions in the target area offer demand-oriented, effective and efficient SAR-supported insurance solutions to farmers and their collectives *(percentage of districts in the two states where RIICE-supported insurance solutions are offered)*

3. Governments and other stakeholders use the remote sensing assisted crop information and advisory system for climate-smart agriculture and climate risk management policies, strategies, and action plans to strengthen farmer resilience and to transfer risks to the insurance sector. *(Ind: number of strategic exchanges and/or formal exchange of letters with state and national level authorities with the responsibility to mandate climate risk resilience and insurance; the number of agriculture institutions /states adopting a SAR-based crop/yield information system within their crop monitoring and climate risk advisory system).*

Under the three outcomes, the key outputs from the India Chapter of RIICE would include:

Output 1.1: The application RIICE technology for farmer resilience in the drought-prone areas of India (states of Karnataka, Uttar Pradesh, and Maharashtra) is validated.

Output 1.2: The awareness and knowledge of agricultural and financial risk management of smallholder farmers, including women farmers, is strengthened through their collectives.

Output 2.1: Insurance companies and distribution partners (including aggregators) are enabled to develop and distribute insurance solutions that cover crop production shortfalls.

Output 3.1: The national policy dialogue, awareness-raising, and stakeholder coordination on the acceptance and use of RIICE technology for agricultural risk resilience including insurance schemes or guidelines are improved.

Component 1a: Application of remote sensing technology for farmer resilience in drylands

1.1 Ground data collection

Ground information was collected through surveying in two distinct field campaigns (Jhansi and Chitrakoot districts) and collectively used to increase the sample size for training data (for class identification) as well as to assess accuracy.

- For Jhansi district, 376 ground data samples were collected during *Rabi* season (2019-20), of which 162 were used for class identification and labeling while the remaining 214 for validation purposes (Figure 1a).

- For Chitrakoot district, 444 ground data samples were collected during *Rabi* season (2019-20), of which 109 were used for class identification and labeling whereas 335 were utilized for validation purposes (Figure 1b).

- Data were collected using stratified random sampling method: stratified by road network and randomized by distance traveled (either every 10 minutes of drive or every 10/15/20 kilometers of drive, depending on road and weather conditions or safety issues/sensitive locations).

- Roughly, 20% of all ground data samples were used for ideal spectra generation and class identification. A greater amount of time spent on ideal spectral sample locations as it involved finding a location and interacting with local farmers/experts for a better understanding of local agricultural systems. However, detailed farmer interviews were conducted in a few locations.

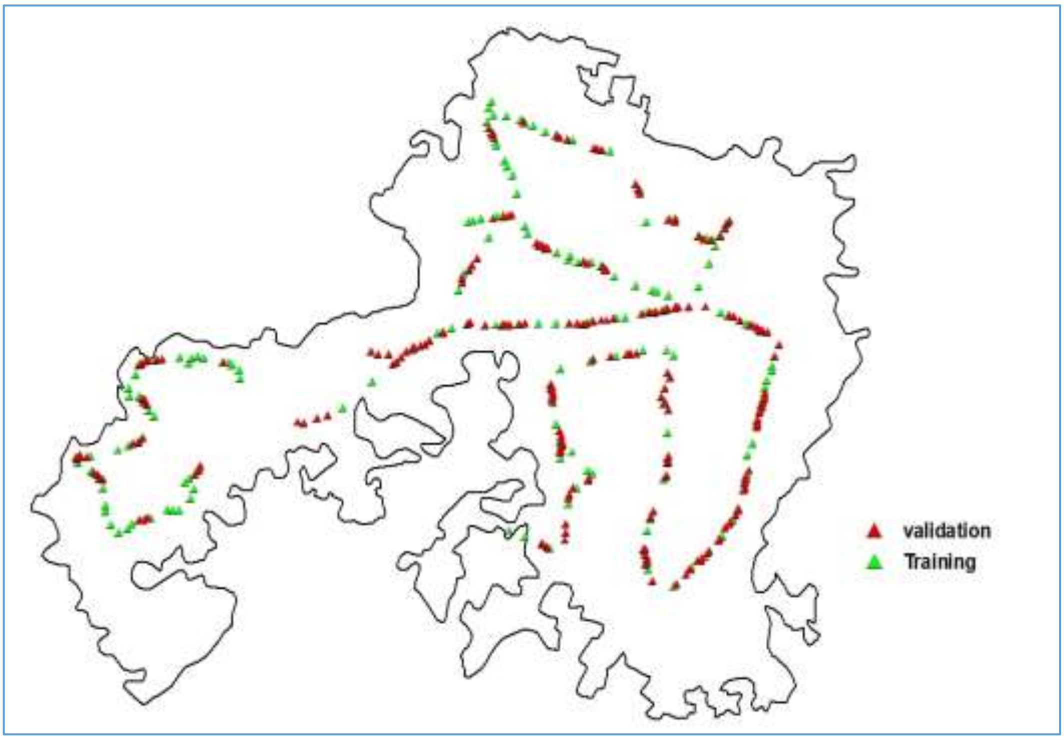

Figure 1a: Ground data collection locations in Jhansi district

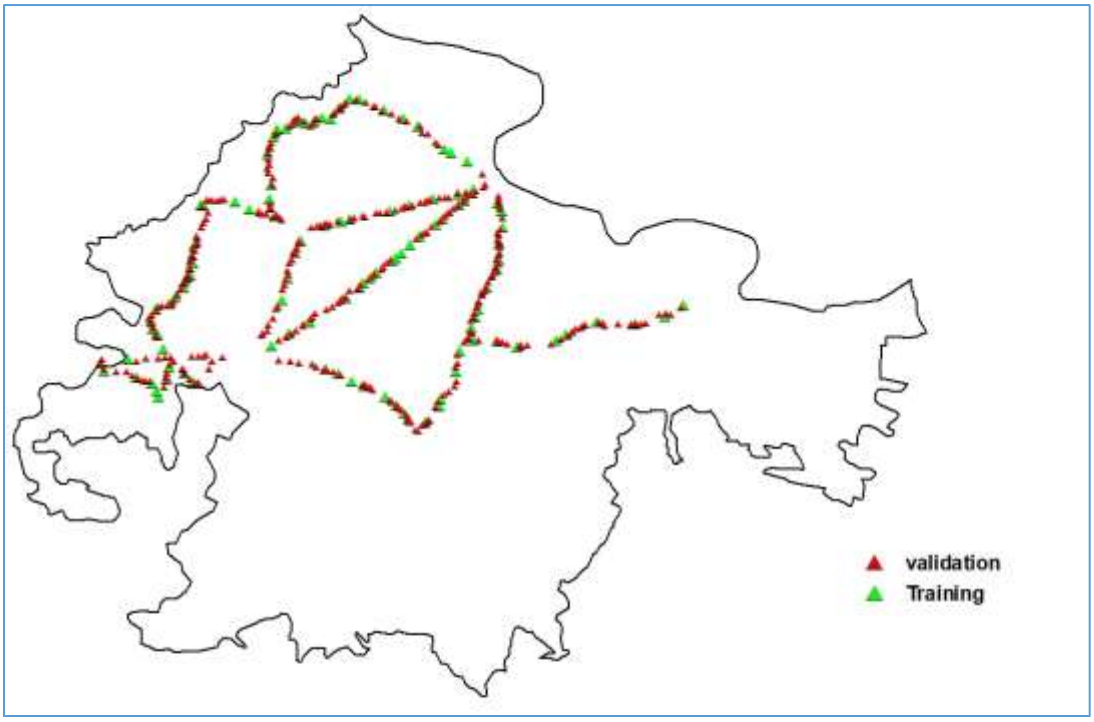

Figure 1b: Ground data collection locations in Chitrakoot district

For each sample, information was collected on the existing crop, irrigation source, soil type and land use/land cover (LULC) with a 250 m x 250 m patch size and geo-located

- Information on the irrigated area surrounding the point was categorized into three classes: small (≤10 ha), medium (10-15 ha), and large (>15 ha).
- Additional information was obtained through personal interviews with farmers and with district agricultural extension officers to determine cropping intensities and crop-types during the previous year. Overall, ground data was systematically collected by adopting the following approach:
    - Cropland water methods: irrigated or rainfed
    - Cropping intensity: single crop (SC), double-crop (DC) or continuous crop (CC)
    - Phenology: *Kharif* or season 1 (June-October), *Rabi*, or season 2 (November-February).

The ground data collection covered major cropland areas in *Rabi* season. These locations were chosen based on the advice of the district agricultural extension officer to ensure adequate sample representation of major crops. A minimum of two photographs was captured at each location for a better understanding of the LULC pattern. Information also collected on planting dates, cropping intensity (single or double-crop), percentage canopy cover, etc. Further, information for location, which was not accessible due to road condition and time constraints obtained from respective agriculture and irrigation departments. LULC names and class labels are assigned in the field according to the ground data collection protocol(Gumma et al. 2014; Thenkabail et al. 2009b).

1.2 Methodology for mapping of cropping patterns

The process begins with mapping LULC using spectral matching techniques using Sentinel 2-time series data. Six bands of Sentinel-2 data at 10 m resolution obtained for the two districts – Jhansi and Chitrakoot for the period of November2019 to March 2020. For each month, images with minimum cloud cover are identified and used. Sentinel-2 datasets are available in the public domain and are pre-calibrated (https://earthexplorer.usgs.gov/). The large swath width of 290 km with a revisit time of 2-3 days at mid-latitudes because of the two-satellite constellation of Sentinel-2 makes it more attractive for mapping large crop areas. The list of Sentinel-2 bands used in the present study is furnished in Table 1. Twenty-four bands (six bands from each of the Sentinel-2 images for the four months) were stacked and used for classification.

Table 1. Sentinel-2 bands used for classification, and their spatial resolutions

Band	Resolution (m)
Band 2 – Blue	10
Band 3 – Green	10
Band 4 – Red	10
Band 8 – NIR	10
Band 11 - SWIR 1	20
Band 12 - SWIR 2	20

The unsupervised classification was used to generate initial classes. The unsupervised ISOCLASS cluster algorithm (ISODATA in ERDAS Imagine 2016TM) runs on the 24-band stack generated at initial 160 classes, with a maximum of 60 iterations and a convergence threshold of 0.99. Although ground survey data was available at the time of image classification, unsupervised classification was used to capture the complete effect of all wavelengths over a large area. The use of unsupervised techniques is recommended for large areas that cover a wide and unknown range of vegetation types, and where landscape heterogeneity complicates the identification of homogeneous training sites. The identification of training sites is particularly problematic for small and heterogeneous irrigated areas.

LULC classes were identified based on temporal signatures along with ground survey data (Figure 2). Crop growth stages were observed including the length of growing periods (LGPs) and cropping pattern from temporal signatures, such as (a) onset of cropping season (e.g., monsoon and winter); (b) duration of cropping season such as monsoon and winter; (c) magnitude of crops during different seasons and years (e.g., water stress and normal years); and (d) end of the cropping season.

The process of labeling and class identification was done based on spectral matching techniques (SMTs) (Gumma et al. 2018; Gumma et al. 2016;Gumma et al. 2015). Initially, 160 classes were grouped from the unsupervised classification based on spectral similarity or closeness of class signatures. Each group of classes was then matched with ideal spectral signatures and ground survey data, and class names assigned. Classes with similar time series and land cover were merged into a single class, and classes showing significant mixing, e.g., homogeneous irrigated areas and forest were masked and reclassified using the same ISOCLASS algorithm. This resulted in 11 classes of LULC for Jhansi district, with five crop classes. Similarly, there were 12 LULC classes with six crop classes in Chitrakoot district. While class aggregation could have been performed statistically using a Euclidean or other distance measure. The study employed a user-intensive method that incorporates both ground survey data and high-resolution imagery to avoid lumping classes that might be spectrally similar but have a distinct land cover. The signatures of some classes differed only in one or two months, which would have resulted in the merging of the classes if an automated similarity index was used.

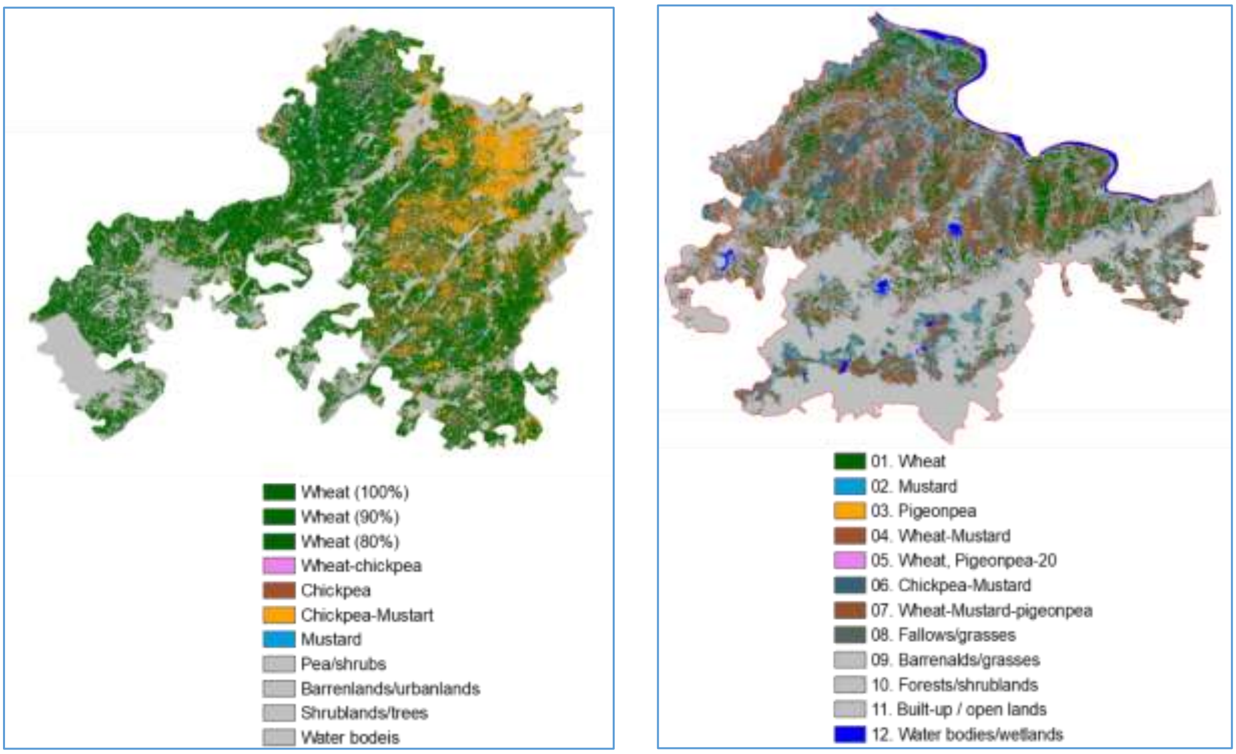

Figure 2: Crop type maps for Jhansi and Chitrakoot districts for Rabi 2019-2020.

1.3 Methodology for the mapping length of the growing period

The length of growing period maps furnishes start, peak, and end of the season (Figure 3a and 3b). These maps generated using a temporal stack of NDVI images derived from Sentinel-2 satellite data. The start of the season map shows the date of the emergence of the crop and not the sowing date. NDVI changes could be noticeable only when there is a crop growth aboveground stage. The peak of season map indicates the date at which the crop biomass is at its peak (i.e., NDVI is maximum during crop cycle). End of season dates is determined as the period when the NDVI drops, indicating the harvest period of the crop.

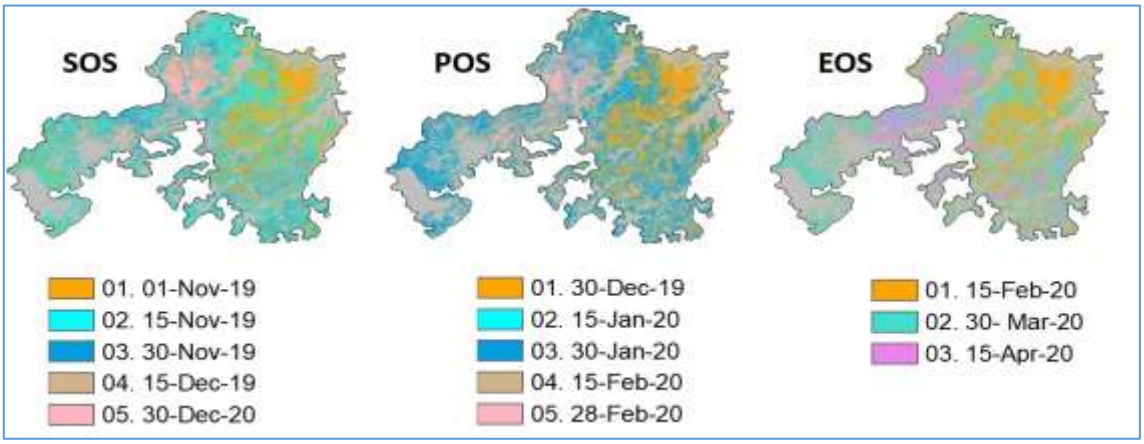

Figure 3a: Maps showing the length of the growing period for Jhansi district for Rabi 2019-20.

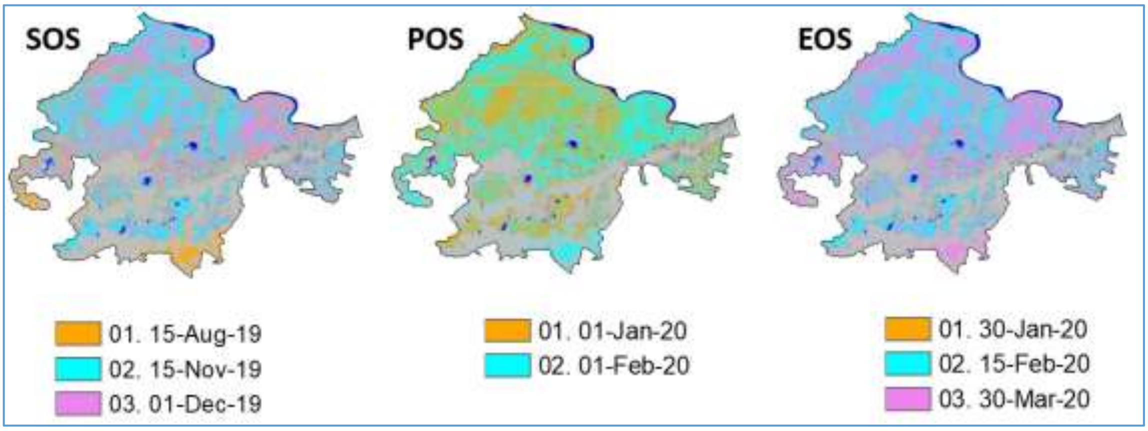

Figure 3b: Maps showing the length of the growing period for Chitrakoot district for Rabi 2019-20.

1.4 Accuracy assessment

Ground data points were used to assess the accuracy of the classification results based on a standard procedure (Congalton and Green 1999; Congalton and Green 2008; Jensen 1996), to generate an error matrix and accuracy measures for each land use/land cover map of each district. 214sample points in Jhansi district and 335 sample points in Chitrakoot district were used for validation of LULC maps. Error matrices (Farr and M. Kobrick), Cohen's kappa coefficient (κ) are commonly used for accuracy assessment. These are useful when building models that predict discrete classes or when classifying imagery. κ can be used as a measure of agreement between model predictions and reality (Congalton 1991) or to determine if the values contained in an error matrix represent a result significantly better than random (Jensen 1996). $\kappa$is computed as:

$$\kappa = \frac{N\sum_{i=1}^{r} x_{ii} - \sum_{i=1}^{r}(x_{i+} \times x_{+i})}{N^2 - \sum_{i=1}^{r}(x_{i+} \times x_{+i})} \quad (1)$$

where N is the total number of sites in the matrix, r is the number of rows in the matrix, x_{ii} is the number in row $i$and column i, x_{+i} is the total for row i, and x_{i+} is the total for column i(Jensen 1996). The error matrices for the classified maps of the three districts for *Rabi* season, including overall accuracy, producer's and user's accuracies, and kappa coefficient are given in Tables 2a and2b.

Table 2a: Error matrix for Jhansi *Rabi* season cropping pattern map								
Crop	Wheat	Wheat-pea	Chickpea	Chickpea-mustard	Other LULC	Grand Total	User's accuracy	Producer's accuracy
Wheat	87	3	3	3	1	97	0.90	0.87
Wheat-pea		18	1			19	0.95	0.67
Chickpea	3	1	15	3		22	0.68	0.71
Chickpea-mustard	8	4	1	45		58	0.78	0.88
Other LULC	2	1	1		14	18	0.78	0.93
Grand Total	100	27	21	51	15	214	Overall accuracy	0.84
Kappa coefficient								0.77

Table 2b: Error matrix for Chitrakoot *Rabi* season cropping pattern map									
Crop	Wheat	Mustard	Wheat-Mustard	Wheat, *pigeonpea*	Chickpea-Mustard	Wheat-Mustard-*Pigeonpea*	Grand Total	User's accuracy	Producer's accuracy
Wheat	86				1		87	0.99	0.88
Mustard	7	14		1			22	0.64	1.00
Wheat-Mustard			96		1		97	0.99	1.00
Wheat, *Pigeonpea-*				12			12	1.00	0.92
Chickpea-Mustard	5				23		28	0.82	0.92
Wheat-Mustard -*Pigeonpea*						89	89	1.00	1.00
Grand Total	98	14	96	13	25	89	335	Overall Accuracy	0.96
Kappa Coefficient									0.94

Component 1b: Crop models for predicting yield and advocacy of climate-smart practices

The APSIM model is used to simulate yield at point/field scale using observed data collected from the field. Meteorological, crop management data along with soil information is required to simulate the model for yield assessment. Significant efforts have been made towards primary data collection such as weather, crop management, and gravimetric soil moisture measurements at three project sites (Buldhana, Vijayapura, Chitrakoot) from the past six months. Moreover, efforts were directed towards the analysis of primary data collected from monitoring surveys and simulated the APSIM sorghum model for yield assessment at the field scale.

Data collection

To run the model at the point scale, weather data was collected from the AWS installed in the project site. A total of 20study fields were identified from DFI project pilot villages for generating the time series monitoring data. For example, 10 *pigeonpea* and 10 sorghum study fields are identified in the Chitrakoot district because these crops are major crops in the district. Figure 4 shows the location of AWS and study field locations where gravimetric soil moisture measurements and crop management data were collected for crop model simulations.

Figure 4: Locations of AWS and monitoring fields in pilot villages of Chitrakoot district.

Meteorological data such as rainfall, solar radiation, maximum and minimum temperature collected from AWS was used to prepare a weather input file (. met file) for model simulation. Figure 5 shows the time series data of rainfall, soil moisture collected at 20 cm, 40 cm, and 60 cm depths from 17th June 2019 to 29thFebruary 2020 in Chitrakoot district. Rainfall days observed from June to September shows a significant response to the soil moisture at different depths. Initial soil moisture data observed at the time of installation is less than 30 percent at all layer depths and gradually decreased due to less rainfall until the first week of July. After that, there were consecutive rainfall days leading to a rapid increase in soil moisture from 25 percent to above 40 percent. It is observed that the increase in soil moisture decreases with a layer depth of soil moisture due to natural infiltration into deep soil layers. Soil moisture values at all depths started decreasing from October to November month due to no rainfall days. Soil moisture suddenly jumped to its maximum due to irrigation in December and little rainfall days during January also indicate the increase in soil moisture.

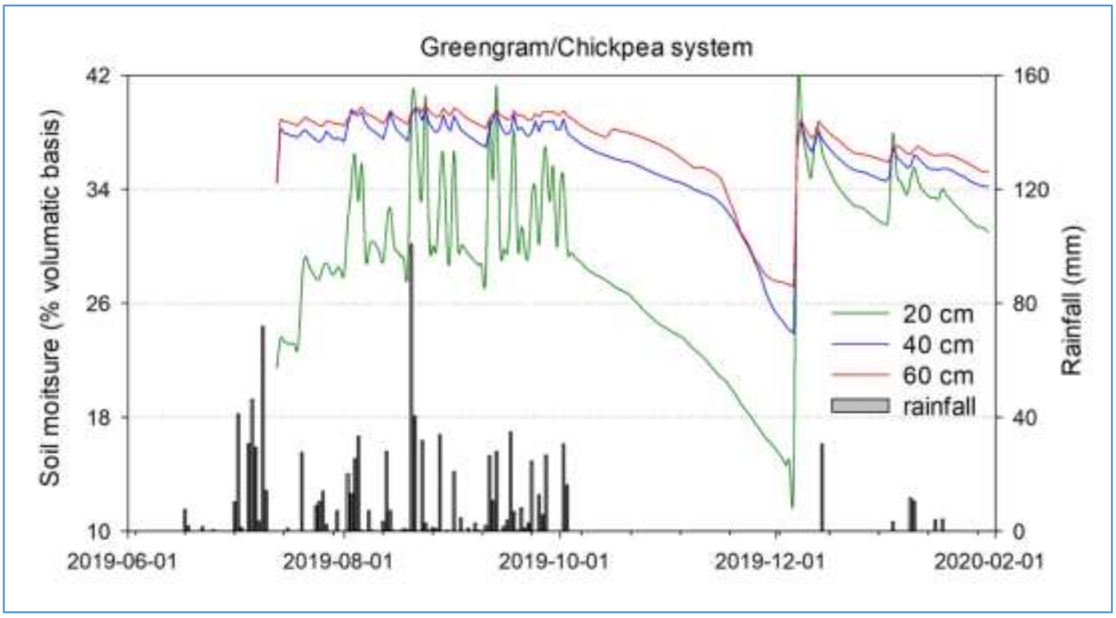

Figure 5: Daily rainfall and soil moisture data at different depths near AWS location

Crop model simulation requires crop management data such as crop variety, field location, sown area, sowing date, source of Irrigation, the quantity of fertilizer application, planting density, row spacing, planting depth, irrigation type, no. of irrigations, date of irrigation, crop stage window information and yield. A total of 20study fields were identified for crop management data and gravimetric soil moisture measurements at different depths for model calibration. Table 3 summarizes the crop management data collected from 20 study fields among the two study crops. Two major cropping systems observed in DFI pilot villages are: 1) Pigeonpea is sown along with sorghum as an intercropping, where sorghum crop harvests in December while pigeonpea harvests in March/April. In another cropping system, sorghum is cultivated during the *Kharif* season followed by wheat/chickpea in the post-rainy season.

Local crop varieties of pigeonpea and sorghum were sown in the study field sites between 29 June and 10 July through the broadcasting method of sowing. Planting density in pigeonpea is 16 plants and 12 plants in case of sorghum per square meter area. The average urea application in the study field sites was 30 kg/acre in sorghum fields and about 20kg/acre or no urea applied for pigeonpea fields. On average, leaf development, flowering, and fruiting in sorghum crops were initiated after 7 days, 110 days, and 140 days after sowing respectively. The average length of sorghum cropping period from sowing to harvesting is about 160 days and the average yield is 1.98 tons per hectare in study sites.

Table 3 Field observations from study fields

Sl	Crop	Inter Crop	Crop ratio	Crop variety	Field Area (Acre)	Farmer Name	Sowing date	Harvesting date	Urea application (Kg/acre)	Total yield (quintals)
1	*Pigeonpea*	Sorghum	80-20	Local	0.6	Shiv SwaroopPyagi	10-Jul	NA	No	NA
2	*Pigeonpea*	Sorghum	90-10	ICPL-87119	1	Ashvani Mishra	1-Jul	NA	20	NA
3	*Pigeonpea*	Sorghum	90-10	Local	1	Umesh Chandra patel	8-Jul	NA	20	NA
4	*Pigeonpea*	Sorghum	90-10	ICPL-87119	1	Raj Karan Yadav	4-Jul	NA	20	NA
5	*Pigeonpea*	Sorghum	80-20	Local	1.5	Prakash Chandra Mishra	7-Jul	NA	35	NA
6	*Pigeonpea*	Sorghum	95-05	Local	0.8	Rambabu Tripathi	6-Jul	NA	30	NA
7	*Pigeonpea*	Sorghum	95-05	Bahar	0.8	UmeshDwivedi	8-Jul	NA	25	NA
8	*Pigeonpea*	Sorghum	95-05	Local	0.4	Rajesh Gupta	9-Jul	NA	No	NA
9	*Pigeonpea*	Sorghum	98-02	Bahar	1	Ram kesh Pandey	5-Jul	NA	20	NA
10	*Pigeonpea*	Sorghum	90-10	Local	0.4	Suresh Arak	10-Jul	NA	No	NA
11	Sorghum	-	100	Local	0.8	Kamta Prasad Dwivedi	2-Jul	18-Dec	30	4.5
12	Sorghum	-	100	CSH-23	0.6	Kripa Shankar Dwivedi	6-Jul	18-Dec	20	6.0
13	Sorghum	-	100	Local	0.4	Santhosh Patel	3-Jul	18-Dec	20	2.5
14	Sorghum	-	100	Local	0.6	Sharvan kumar patel	4-Jul	17-Dec	30	4.0
15	Sorghum	-	100	Local	0.4	Ram Dayal Patel	5-Jul	20-Dec	20	3.0
16	Sorghum	-	100	Local	0.6	Ram Bhavan	7-Jul	18-Dec	25	4.5
17	Sorghum	-	100	Local	0.4	Ram Sharan Yadav	10-Jul	16-Dec	20	2.5
18	Sorghum	-	100	Local	0.4	Ram Bharasa yadav	5-Jul	16-Dec	20	3.0
19	Sorghum	-	100	CSH-23	0.8	Dinesh Patel	7-Jul	17-Dec	40	6.0
20	Sorghum	*Pigeonpea*	80-20	CSH-23	0.6	Hari Krishna tripathi	29-Jun	18-Dec	30	4.8

Gravimetric soil moisture analysis

Exploring the soil moisture dynamics and adaptations to plant responses plays an important role in water-limited areas. Plant physiological process and growth is directly related to the amount of soil moisture stored in the soil layer. To analyze the soil moisture dynamics in pigeonpea and sorghum crops, gravimetric soil moisture measurements were collected in field experiment sites at 0-15, 16-30, 31-45, 46-60 cm depths at the weekly interval. Figure 6 presents the temporal and spatial variability of soil moisture in different depths. Soil moisture in 0-15 cm and 0-30 cm shows high variability compared with soil moisture at 31-45 cm and 46-60 cm depths.

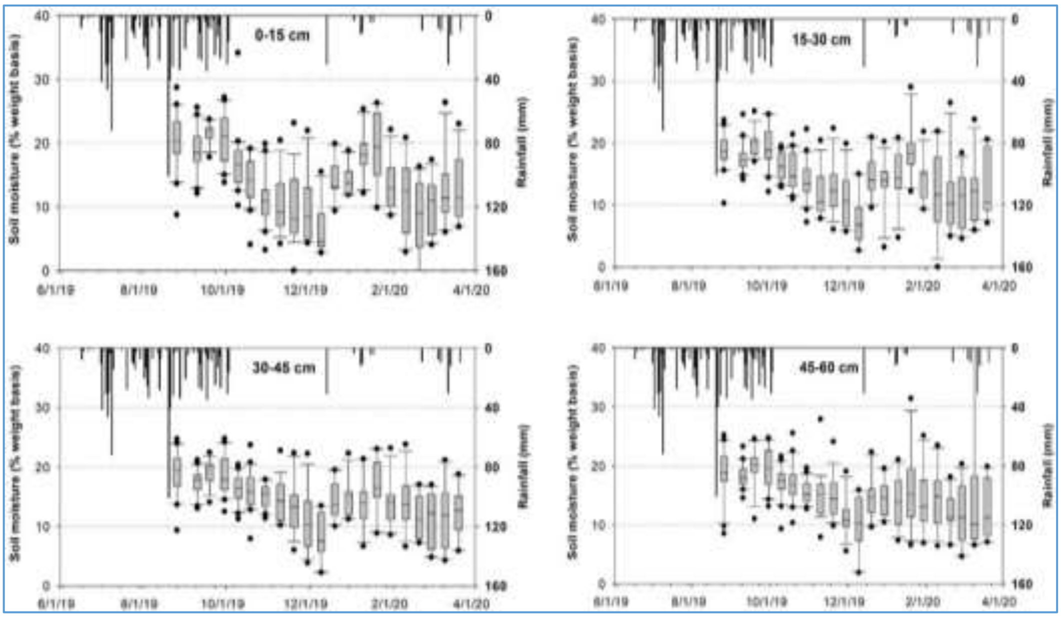

Figure 6: Temporal and spatial variability of gravimetric soil moisture at study sites

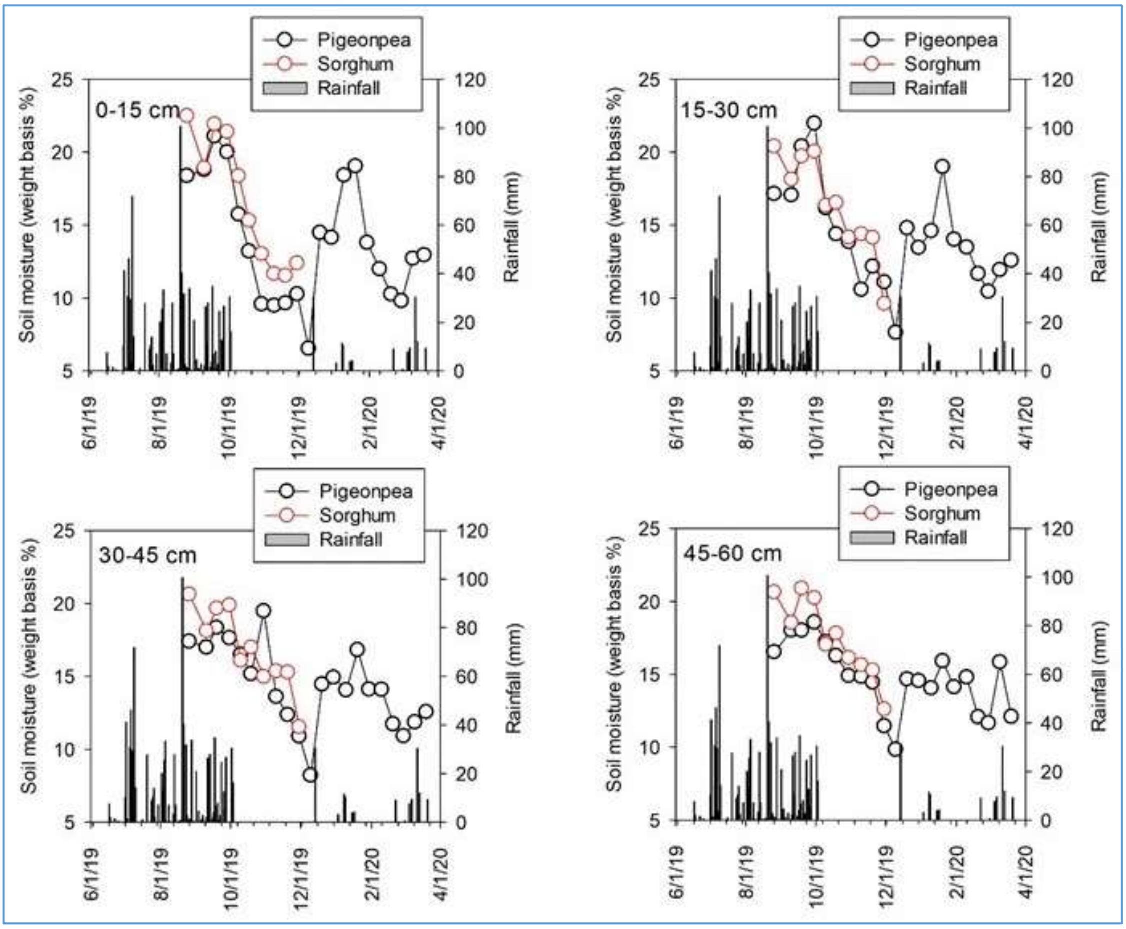

Figure 7: Comparison of soil moisture use in pigeonpea and sorghum fields

Figure 7 shows the soil moisture use at 0-15,15-30, 30-45, 45-60 cm depths in pigeonpea and sorghum fields. It is observed that seasonal changes in soil moisture related to meteorological data and the amount of soil water stored in different depths of soil layers. The meteorological conditions in the monitoring fields are unique, soil moisture dynamics in the monitoring fields can be attributed to soil water uptake or soil water use in pigeonpea and sorghum fields. Soil water uptake by pigeonpea is more compared to sorghum in different soil layers as shown in Figure 7.

Model simulation

The APSIM crop simulation model is used for sorghum yield assessment using the data collected from 10 field sites. Daily weather data obtained from the automatic weather station was used for model simulation. Based on the soil profile description observed from the fields, a suitable generic soil profile available in the model was selected to set up the model. Crop management dataset from 10 fields was used.

In addition to the crop management data, the model requires various parameters related to sorghum crop and soil layers. As there were no observed values, set default values found in APSIM descriptor files were used. It was observed that existing cultivars for the sorghum overestimated the biomass and yield during the preliminary iterations. Crop specific coefficients were modified for sorghum crop growth stages described in the model for better yield assessment.

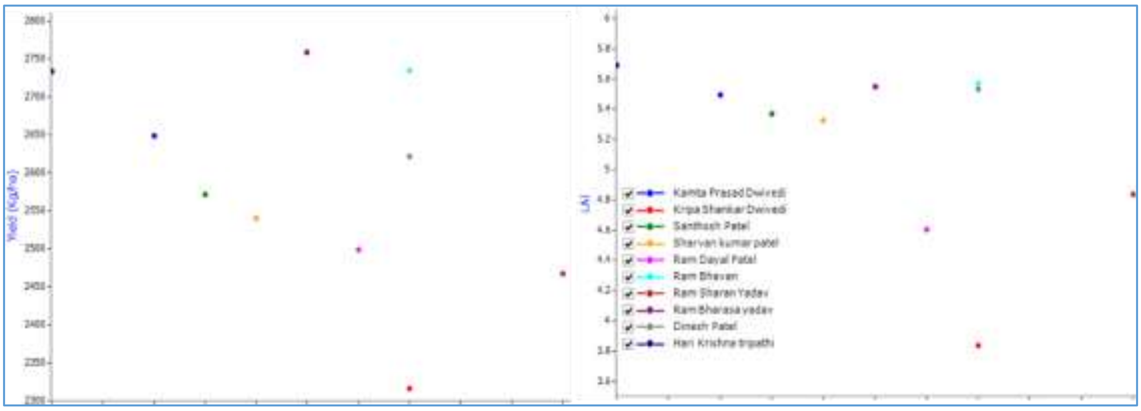

Figure 8: Simulated sorghum yield and LAI values from different field sites.

Figure5 shows the simulated yield and LAI values obtained from the APSIM-sorghum model. The simulated yield ranges from 2.3 to 2.8 tons per hectare whereas the observed yield ranges from 1.5 to 2.7 tons per hectare. This is mainly due to no variation in the crop management data where the soil and meteorological data are unique in the iterations. Within the crop management module, sowing dates were set to actual sowing dates, and late sorghum variety was used to match the length of the cropping period observed in the fields. As per the model simulation, the sorghum crop was harvested between 16 September and 29 September. Actual harvesting was done in mid of December, which is nearly 60 days after the model harvesting date.

The model was able to simulate the yield and LAI within the acceptable range but over-estimated due to differences in length of cropping periods. LAI values collected from the field sites can be used for model calibration to improve the accuracy in yield assessment.

Crop production functions will be developed using the simulated yield at point scale such as i) NDVI vs. Yield; ii) LAI vs. Yield; iii) Crop stress vs. Yield; iv) ET vs Yield are the next steps.

Analyze yield at a district scale using the calibrated crop production functions. Remote sensing Indices described above will also be used to calibrate the model at the district scale.

Component 1c: Assessment of yield and income loss due to hailstorms in Chitrakoot and Banda districts

The Bundelkhand region of Uttar Pradesh experienced an extreme weather event during March 2020 when several areas of this region suffered due to hail storms. This was the period when *Rabi* crops were either in grain formation stage or at maturity while long-duration *Kharif* crop like *pigeonpea* was about to be harvested. Chitrakoot and Banda districts suffered heavily due to the untimely hailstorms. Keeping in view the lockdown due to the COVID19 pandemic, reaching out to farmers physically did not possible to assess the extent of the damage. However, information was gathered from them over the telephone to assess the extent of damage due to hailstorms.

Methodology: Conducted a telephonic Interview of farmers from hailstorm-affected areas of the DFI project in Banda and Chitrakoot districts. Questions focused on the cultivated area, total harvested quantity, and damage due to hailstorm during March 2020 in comparison with their yield levels in the previous year estimated. Below are the study outcomes:

Chitrakoot district:

Twenty farmers were surveyed from Rasin and Rauli villages of Chitrakoot district. The total area cultivated by them was 126 acres. Out of that, 33% area was under wheat; 25% under chickpea; 12% mustard, and 30% pigeonpea. Wheat, chickpea, and mustard were *Rabi* season crop; whereas pigeonpea was sown in *Kharif* and harvested by end of *Rabi* as it was long duration crop (>220-250 days). Table 4 and Figure 9 show the average crop yield of major crops along with their maximum and minimum range during the current year (2020) and compared to the yield realized during the previous year (2019). Due to a hailstorm in March 2020, there was significant damage in terms of crop yield and also grain quality. Yield reduction in pigeonpea, chickpea, and mustard ranged from 55% to 85%, as all these crops were at the harvesting stage during the incidence of a hailstorm. The survey also revealed that some of the farmers did not even harvest chickpea as it would cost them more than simply leaving the remaining crop in the field. Wheat yield was reduced to the extent of 30%. The average wheat yield in the current year was found 9.2 Q/acre compared to 13.6 Q/acre in 2019 showed a 4.4 Q reduction per acre on an average.

Table 4. Reduction in crop yield during the year 2020 due to hailstorm

Crop	Year 2019	Year 2020	Per cent reduction
Wheat	13.6 (12.5-16.9)	9.2 (6.7-12.5)	32%
Chickpea	5.0 (2.5-7.5)	1.2 (0.6-2.5)	76%
Mustard	7.3 (3.8-8.8)	3.2 (0.8-5.0)	56%
Pigeonpea	4.8 (1.3-7.5)	0.9 (0.3-1.4)	82%

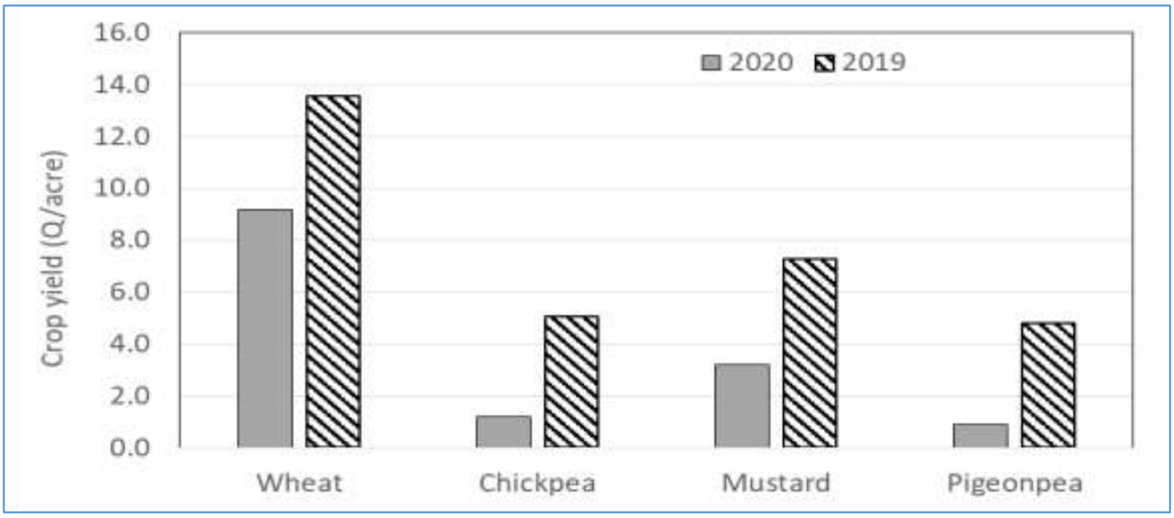

Figure 9: Yield loss due to hailstorm in wheat, chickpea, mustard and pigeonpea crops in Chitrakoot during the year 2020

We also discussed with farmers about the quality of grains of these crops. As per their opinion, out of total production, 40% wheat grain was with the best quality; 30% moderate and 30% was of poor quality (dark and shrivelled). They will be able to sell good quality grains at about INR 1900/Q; moderate-quality with a slightly reduced price (INR 1600-1700/Q); and poor quality grain to be consumed at home or for livestock depending on its final quality. If sold the market value of this quality grains would be around INR 1000-1200/Q. Based on this, the estimated reduction in net profit under wheat accounted for INR 11,000/acre (reduction of more than 40%) compared to the previous year.

Banda district

We interviewed 15 farmers at DFI project villages in Banda districts. The total cultivated land with different *Rabi* crops was about 50 acres. Out of this, wheat, chickpea, and mustard occupied 38%, 30%, and 32%, respectively. Data showed hailstorm and unexpected rains reduced the wheat, chickpea, and mustard yield by 24%, 29%, and 51% respectively. The average wheat yield was 16.1 Q/acre compared to the expected yield of over 21Q/acre (based on 2019 yield levels). Please, see the details and illustrations in Table 5 and Figure 10. Due to hailstorms in March 2020, yield in mustard came down by 50% (3.2 Q/acre harvested vs 6.5 Q/acre expected). The average chickpea yield also was less by 29% (4.2 Q/acre harvested vs 6.0 Q/acre expected). Unlike in Chitrakoot, the quality of grains in Banda was not affected in wheat and chickpea crops; and farmers are expecting to sell them @ 2000 Rs/Q and 4000 Rs/Q, respectively. However, there the quality of mustard grains was affected slightly which has resulted in decreased oil content.

Farmers also admitted that the application of micronutrients has helped in reducing crop damage and retaining grain quality. Farmers who applied $ZnSO_4$ and other micronutrients reported that crops did not suffer from lodging and their grain quality was not affected much. A similar impression was also recorded in Chitrakoot district. In the absence of micro and secondary nutrients, the damage would have been severe.

Table 5. Reduction in crop yield due to hailstorms in Banda district			
Crop	Harvested in 2020	Expecting before hailstorm event	Percent reduction
Wheat	16.1 (10-25)	21.3 (10-32)	24%
Chickpea	4.2 (1.6-7.5)	6.0 (4.5-7.5)	29%
Mustard	3.2 (1-5)	6.5 (4-10)	51%

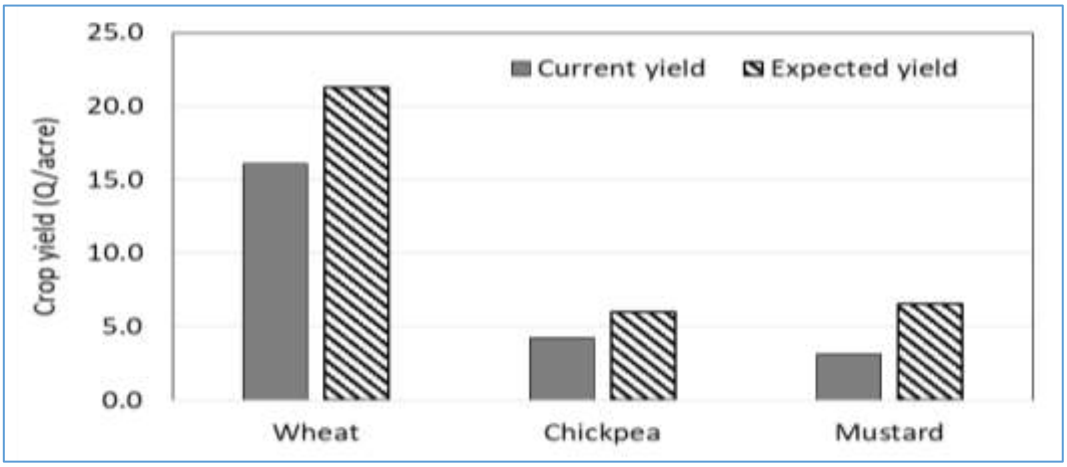

Figure 10: Yield loss due to hailstorms in wheat, chickpea and mustard crops in Banda during 2020.

Component 2a: Capacity strengthening of Farmer collectives as knowledge delivery entities in Insurance

The role of BASIX Consulting is broadly to facilitate the following:

- Provide handholding support to selected FPOs (maximum of 20 FPOs in the Karnataka and Bundelkhand geographies of the project area) to enable them to serve as knowledge delivery entities for Insurance. This would involve capacitating the FPOs to translate the agro-advisories (especially the climate/weather/satellite related) into locally understood terminology and sharing the same with the member farmers of the FPOs through a variety of modes.

- Conduct capacity building of FPOs for strengthening FPOs as business entities for distribution of Insurance. Here the focus will be especially on capacitating the FPOs to operate the crop insurance activities in a financially sustainable manner over some time.

- Develop and roll out the business model for facilitating crop insurance and also negotiate arrangements between FPOs and insurers for effective implementation of the crop insurance program.

- Explore the possibility of supporting and handhold the FPOs to establish common service centers for crop insurance.

- Facilitate to develop and implement monitoring and evaluation platform for capturing the regular crop assessment viz., crop type, growth, crop damage, and yield estimation to assess project impact and help support insurance product development.
- Facilitate and work with the identified agency/consultant for the analysis of data, modeling risks, and quantifying the various insurance options for partner FPOs.
- Document case studies and prepare training modules on Insurance from time to time

Key objectives

1. Capacity strengthening of Farmer collectives (FPOs and Farmer collectives) as knowledge delivery entities (Karnataka and Bundelkhand geographies of the project area)
2. Facilitate for Design and Development of innovative Meso-level insurance products
3. Supporting the project team in Policy advocacy for mainstreaming remote sensing-based risk assessment

Progress during *Rabi*, 2019-2020

Institutional partners - *Rabi* 2019

The geographies targeted for *Rabi* 2019 were Jhansi and Chitrakoot in Uttar Pradesh. While in Karnataka, the operations in Vijaypura strengthened and farmer collectives and NGOs identified in Bidar. In Uttar Pradesh, we engaged with eight (8) NGOs and one (1) Farmer collective. In Karnataka, we engaged with SHGs in Ukkali village (Vijayapura district), where BCTS worked directly with their field team. In Bidar, we identified four farmer collectives to work within *Kharif* 2020.

The field teams of BCTS, NGO partners as well as the teams of farmer collectives have been trained on the PMFBY program. IEC material was distributed to farmers and wall paintings displayed in main villages to spread the information on the PMFBY program.

BCTS team with enriched learning's during *Kharif* 2019 had a refined process in geographical coverage by strengthening relationships with the CSCs, networked financial institutions, the Department of Agriculture, and the civil society organizations. These networks supported in identifying a set of targeted villages with a high number of non-loanee farmers. This helped us to focus the training programs/awareness programs to the farmers more effectively.

The following table provides the details of the partners:

Table 6. Details of Farmer organizations / NGOs

State	District	NGO Partner	Farmer collective Partner
Uttar Pradesh	Jhansi	Pragatipath	Bhashneya Farmer Producer Company Ltd.
		Samagra Gram	
		Sewa Mandal	
		Software Academy India	
	Chitrakoot	Gramin Vikas Kendra (ICRISAT- Partner NGO)	
		Nandi Gaushala	
		PragatiMadhyam	
		Sai Jan JagratiSansthan	
Karnataka	Vijaypura	Ukkali Village – SHGs	
	Bidar	Prawarda	Raitha Bandhu Farmers Producer Company Limited
		Ankita	Ashodaya Farmer Producer Company Limited
			Maanjira Farmer Producer Company Limited
			Belaku Farmers Producer Company Limited

PMFBY Enrolments of non- Loanee farmers in *Rabi* 2019 season

We continued to work with the six CSCs identified during the *Kharif* 2019 in both the states. The targeted number of enrolments for *Rabi* 2019 was 3500 and the team was able to achieve 97% of the target (3402). In the first year of operations, BCTS was able to achieve 34% of the total enrolments targeted by BCTS (10000 farmers in two districts) under the cumulative target for the two districts. The enrolments of non-loanee farmers recorded for the year 2019-2020 was 3402. The share of Karnataka was 69.5% with 2365 enrolments and Uttar Pradesh being 30.5% (1037).

PMFBY enrolments are normally higher in the *Kharif* season. However, the targeted approach as mentioned above had resulted in higher non-loanee farmers in *Rabi* 2019. The enrolment rate in *Rabi* 2019 was ~310% higher to *Kharif* 2019 with 2536 enrolments. The share of Karnataka (Vijaypura district) was 74% of the total enrolments for *Rabi* 2019.

The sustained capacity building and awareness programs in both the locations Bundelkhand and Vijaypura districts have resulted in better outturn in the non-loanee farmer’s enrolment. The number of enrolments increased by 4.3 times in the Vijaypura district and twice in the Bundelkhand region of Uttar Pradesh.

The following table provides the details of the enrolments of non-loanee farmers for the year 2019:

Table 7. Details of Non-Loanee Farmers Enrolments

State	*Kharif* -2019	*Rabi* -2019	Total Enrolments (the year 2019)
Karnataka	437	1878	2365
Uttar Pradesh	379	658	1037
Total	816	2536	3402

The following were the key challenges identified in the enrolment process

- CSCs cooperation in the enrolment of the PMFBY applicants was still challenging
- Accessing and conversion of non-loanee farmers was low as the operational geographies are limited (only 2 districts)
- The portal being unresponsive, not operational for uploading the documents.
- BCTS manpower covering the villages is less to bring in the required numbers of enrolments.

Way forward for *Kharif* 2020

Engaging with the stakeholders

BCTS team continued its strong engagement process with different stakeholders to ensure identification, reaching, creating awareness, enrolling, and overall governing of the non-loanee farmer's enrolment into the PMFBY.

However, the impact of the COVID-19 and the restrictions thereof have limited the activities of the team members. The stakeholder's support was also minimal due to the various restrictions imposed, high levels of COVID infections in Jhansi, and Vijaypura. Precious time was lost as the BCTS was not able to take necessary meetings and awareness programs at the grassroots level until May 2020. There were many restrictions on social gatherings.

Apart, there was a sudden shift in the priorities of the NGO partners as their work shifted to health and programs around community awareness on COVID-19. Hence, the support from the NGOs declined during *Kharif* 2020.

This required a change in the tactical approach by the team to target enrolment of the targeted number of 5000 enrolments for *Kharif* 2020. BCTS had envisaged the following changes in the strategy to achieve the targeted enrolment of 5000 non-loanee farmers under PMFBY for *Kharif* 2020.

Expansion of the targeted geographies

While strengthening the fieldwork in the existing districts of Jhansi and Vijaypura, the enrolment team would cover additional districts such as Jaunpur in Uttar Pradesh and Bidar in Karnataka. However, we understood that the COVID restrictions on travel still challenged substantial coverage of the new territories.

Development of new Cadre- the FASAL BIMA MITRA (FBM)

The current project exists until June 2021 and the farmer institutions will need to sustain the PMFBY assistance to its farmer members beyond the timelines of this project. Hence, BCTS envisaged the creation of a cadre/ institutional system be retained such that the enrolment process remains a viable business proposition for the farmer organizations by embracing CSC as a viable and sustainable business activity. BCTS discussed the model with ICRISAT and SDC during the annual review and suggestions taken for implementing the model.

Thus, we developed the cadre of Fasal Bhīma Mitra (FBM) and 14-16 FBMs anchored to cover 1-2 villages each in each district. Upon receiving the training of the PMFBY product, systems and processes, the FBMs intensively covered the villages allotted to them. The key activities undertaken by the FBMs are

- Conduct small group meetings in the village(s)
- Identify non-loanee farmers
- Create awareness on crop insurance (PMFBY)
- Engaging with the CSC and other local stakeholders
- Documentation support to the farmers
- Enrolment support to both CSC and the farmers

Going ahead the FBMs will also be trained (along with the farmer organizations) on the processes and systems of claiming insurance, engaging with relevant stakeholders, etc. This will ensure that the FBMs along with the farmer organizations will be able to serve as a single point of contact for end-to-end services for the PMFBY product.

The following table provides the plan for the FBMs for *Kharif* 2020

Table 8. Details of Fasal Bhīma Mitras

State	Number of FBMs	Number of Villages	Targeted Enrolments
Karnataka (Vijaypura District)	15	15	3000
Uttar Pradesh (3 Districts)	48	67	2000
Total	63	82	5000

Status until June end of *Kharif* 2020

- Complete the *Kharif* -2020 enrolment programs and reach the targeted 5000 enrolments
- Identified and placed the FBMs, trained them, and small group meetings conducted in different villages.
- The finalization of the Insurance companies for the season was delayed in Uttar Pradesh, with no clear indication of when the enrolment window would open.

Component 2b: Enhancing Farmers' Resilience through better Agromet Advisories

The *Kharif* 2019-2020 was the first season for the activity on Agromet Advisories under the project. Advisories were prepared in Marathi and Kannada languages with the help of concerned Nodal Officers at the PDKVV, Akola, and at the RARS Vijayapura under UAS Dharwad. Initially, it was planned that the agromet advisories will be shared with the representatives of farmer collectives, who would then share them with other farmers. However, considering the difficulties in communication and delay in identifying suitable farmer collectives, we met farmers directly, explained agromet advisories to them, and then identified interested farmers in two districts for disseminating the advisories directly to them through the Kalgudi platform.

Initial discussions with farmers revealed that agromet advisories are useful to them and they would like to continue to receive them in the next year also. Meetings with a few farmers are planned at a later stage to collect feedback on the quality and timely receipt of advisories, and benefits accrued if any. During the next *Kharif* season in the year 2020, we may plan for displaying agromet advisories at a central location in the villages for better visibility and spread. Advisories in Hindi for farmers in Chitrakoot district will be initiated from *Kharif* 2020.

In the second and third years of the project period, we propose to enhance the number of participating farmers to a few thousand. This is because of the interest and enthusiasm being shown by the farmers in the villages.

Component 3: Developing innovative Meso-level insurance products

Developing innovative Meso-level insurance products is the need of the hour to mitigate the negative influences of climate change impacts on rainfed cropping systems and farmers' livelihoods. Critical understanding of study locations and assessing the extent and nature of risk in agriculture is the key to moving forward. Detailed need assessment surveys were carried out among farmer collective organizations/community service centers with the help of the BASIX team for determining the prime risk portfolio. It will be followed up with a feasibility analysis for prioritizing an insurance product from a range of insurance product bouquet. Similarly, the project needs to look for insurance companies that can offer an attractive product to meet the requirements, etc.

While the identification of farmer collectives and need assessment surveys were just completed, the project team (Arindom Baidya) is working out the feasibility of a meso-level insurance product for targeted regions. Currently, ICRISAT has engaged an external agency (Weather Risk Management Services Pvt Ltd.) for assessing its relevance and other constraints in its application across study regions. ICRISAT launched an RFP and three organizations – IFMR Lead, Microsave Consulting, and Weather Risk Management Services Pvt Ltd (WRMS) – have responded to it. After reviewing the strengths of each organization and financial proposals, WRMS was selected. WRMS brings in an additional product design capacity, which will be vital for the study, which will start in January 2020. Efforts were also on to identify opportunities to collaborate with WRMS to test-run a meso-level insurance product in Maharashtra.

Table 9. Project outreach activities

Person	Institution represented	Program participated/activity on-going
Murali and Michael	ICRISAT and sarmap	Attended 'Insurance Tech' meeting at Mumbai, organized by the World Bank, during July 2019
Murali and Michael	ICRISAT and sarmap	Participated in Asia Insurance Review Conference on Crop Insurance during September 2019
Murali	ICRISAT	Undertaking MNCFC work for optimization of no. of CCEs covering project locations
Murali	ICRISAT	Undertaking IRICS work for the development of crop stress maps for current *Kharif* season
Sreenath Dixit	ICRISAT	Application of drone technology for generating crop extent maps in Karnataka
Murali	ICRISAT	Attended Geospatial Conference held at Hyderabad, 2019

Component 4: Policy advocacy for mainstreaming remote sensing-based risk assessment

During the project period, three major activities were initiated for mainstreaming the remote sensing-based risk assessment in the country. The activity-wise details are furnished below:

1. An initiative of the Mahalanob is National Crop Forecast Centre (MNCFC), Ministry of Agriculture, Govt. of India for optimization of Crop Cut Estimates (CCEs)

2. International Reinsurance and Insurance Consultancy and Brokering Services Private Limited (IRICS) adopts RS for development of crop stress maps (*Kharif* season)

3.Agriculture Commissioner, Government of Andhra Pradesh keen to use RS products for monitoring croplands and yield estimates (a proposal under discussion)

4. We have continued *Rabi* season yield assessment for selected crops (rice, wheat) in Telangana and UP

ICRISAT-India (Headquarters)
Patancheru, Telangana, India
icrisat@cgiar.org

ICRISAT-India Liaison Office
New Delhi, India

ICRISAT-Mali (Regional hub WCA)
Bamako, Mali
icrisat-w-mali@cgiar.org

ICRISAT-Niger
Niamey, Niger
icrisatsc@cgiar.org

ICRISAT-Nigeria
Kano, Nigeria
icrisat-kano@cgiar.org

ICRISAT-Kenya (Regional hub ESA)
Nairobi, Kenya
icrisat-nairobi@cgiar.org

ICRISAT-Ethiopia
Addis Ababa, Ethiopia
icrisat-addis@cgiar.org

ICRISAT-Malawi
Lilongwe, Malawi
icrisat-malawi@cgiar.org

ICRISAT-Mozambique
Maputo, Mozambique
icrisatmoz@panintra.com

ICRISAT-Zimbabwe
Bulawayo, Zimbabwe
icrisatzw@cgiar.org

ICRISAT appreciates the support of CGIAR investors to help overcome poverty, malnutrition and environmental degradation in the harshest dryland regions of the world. See http://www.icrisat.org/icrisat-donors.htm for full list of donors.