Usability of extended range and seasonal weather forecast in Indian agriculture

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सार - कृषि उत्पाद में मौसम की महत्वपूर्ण भूमिका होती है। फसल की बुआई के दौरान और बुआई से पहले मौसम की जानकारी बहुत महत्वपूर्ण भूमिका निभाती है। यदि मौसम की जानकारी उचित समय पर पहले दी जाए तो इससे कृषकों को अपने संसाधनों को एकत्रित करने और अच्छी तरह से उपयोग करके फसल की पैदावार बढ़ाने में प्रोत्साहन मिलेगा। वर्तमान समय में भारत मौसम विज्ञान विभाग (आई एम डी) पृथ्वी विज्ञान मंत्रालय (एम ओ इ एस) कृषि मौसम परामर्शी सेवाएं कृषकों को देकर उन्हें प्राकृतिक संसाधनों का दक्षता के साथ उपयोग करने में मदद कर रहा है, इसका उद्देश्य है कि मध्य अवधि मौसम पूर्वानुमान (MRWF) के उपयोग के द्वारा कृषि उत्पादन में वृद्धि लाई जाए। परन्तु इसके साथ-साथ यह भी महत्वपूर्ण है कि फसल की बुआई के पूर्व और फसल की बुआई के समय जलवायविक सूचनाओं को विस्तृत सीमा और ऋतुनिष्ठ मौसम पूर्वानुमान के साथ मिश्रित करके दिया जाए जिससे कि कृषि-प्रणाली को मौसम में बदलाव की वृद्धि होने पर भी सही तरीके से अपनाया जा सके। इन्हीं बातों को ध्यान में रखकर भारत मौसम विज्ञान विभाग भारतीय उष्णकटिबंधीय मौसम विज्ञान संस्थान (IITM) पुणे के साथ मिलकर विस्तृत अवधि और ऋतुनिष्ठ मौसम पूर्वानुमान तैयार करना आरंभ किया है। इस पूर्वानुमान की मदद से भारत मौसम विज्ञान विभाग के कृषि मौसम प्रभाग में समूचे देश के लिए कृषि मौसम परामर्शियाँ पाक्षिक और पूरी ऋतुओं के लिए तैयार करना आरंभ कर दिया गया है कि कृषकों से प्राप्त हुए सुझावों के आधार पर ऐसा समझा गया कि कृषकों को उनके कृषि कार्य के लिए व्यापक योजना बनाने के लिए विस्तृत अवधि और ऋतुनिष्ठ अवधि के पूर्वानुमान की जानकारी पहले दिए जाने की आवश्यकता है। इन्हीं बातों को ध्यान में रखकर विस्तृत और ऋतुनिष्ठ पूर्वानुमान का प्रयोग आरंभ में प्रायोगिक तौर पर संतुलित दक्षता के साथ कृषि मौसम पूर्वानुमान देने के लिए किया गया है। इस शोध पत्र में इस विषय पर प्रकाश डाला गया है कि किस प्रकार विस्तृत और ऋतुनिष्ठ पूर्वानुमान का उपयोग तेजी से बदलते परिवेश में अच्छी कृषि के लिए कृषि मौसम परामर्श के माध्यम से किया जा सकता है और मौसम से संबंधित अनिश्चितताओं को एक प्रचालनात्मक साधन के तौर पर अपनाया जा सकता है और इसके जरिए कृषकों की मदद की जा सकती है। देश के भिन्न-भिन्न स्रोतों से प्राप्त हुए सुझावों से यह सत्यापित होता है कि कृषि संबंधी यथोचित निर्णय लेने के लिए विस्तृत और ऋतुनिष्ठ मौसम पुर्वानुमान आवश्यक और महत्वपूर्ण है।

ABSTRACT. Weather plays an important role in agricultural production. It plays a major role before and during the cropping season and if the same is provided well in advance, it results in inspiring the farmers to organize and activate their own resources in the best possible way to increase the crop production. At present, India Meteorological Department (IMD), Ministry of Earth Sciences (MoES) is rendering Agro-meteorological Advisory Services to help the farmers for efficient use of natural resources along with the aim of improving agricultural production by using the Medium Range Weather Forecast (MRWF). But, it becomes more and more important to provide climatological information blended with extended range and seasonal weather forecast before the start as well as during the cropping season in order to adapt the agricultural system to increase weather variability. In view of this, IMD in collaboration with Indian Institute of Tropical Meteorology (IITM), Pune has started preparation of extended range and seasonal weather forecast. With the help of this forecast, Agricultural Meteorology Division, IMD has started preparation of Agro-met Advisories fortnightly as well as for the season as a whole for the entire country. Based on the feedback from the farmers, it is understood that farmers need prior information of weather on extended as well as seasonal scale to make a comprehensive plan for their farming operations. In view of that, it has been tried initially on experimental scale to use extended and seasonal forecast in agriculture having a modest skill. In this paper elaborate discussion has been made on how the extended range and seasonal weather forecast were useful to develop and apply operational tools to manage weather related uncertainties through agro-meteorological applications for efficient agriculture in rapidly changing environment and ultimately to assist the farmers. The feedback received from various sources in the country justifies the need and importance of extended range and seasonal weather forecast for taking appropriate decisions in agriculture.

Key words – Extended range weather forecast, Seasonal weather forecast, Operational agromet advisories services.

1.   Introduction

IMD generates weather forecasts at different temporal scale *i.e.* short range, medium range, extended range and seasonal scales and these forecasts are used for tactical and strategic decisions in agriculture. At present Medium Range Weather Forecast (MRWF) is used by IMD for generating agro-met advisories for 635 districts twice in a week in collaboration with 130 Agro-met Field Units (AMFUs) located at State Agriculture Universities (SAUs), institutes of Indian Council of Agriculture Research (ICAR), Indian Institute of Technology (IITs) to provide the information in a convenient and timely manner for taking practical decisions for sowing, application of fertilizers, irrigation etc. and these are communicated to farmers through multi-channel dissemination systems. These advisories also provide a very special kind of inputs to the farmers as advisories that can make a tremendous difference to the agricultural production by taking the advantage of benevolent weather and minimize the adverse impact of malevolent weather.

These agromet advisories are prepared based on the weather forecast on a real time basis and proved to be useful in the decision making process in every farm operation, rain water harvesting, crop planning, control of pest& diseases, irrigation scheduling etc. Rathore *et al.*, (2001) also described the use of operational medium range weather forecast and its economic benefit to the farmers in the country. A number of studies showed the usefulness of medium range weather forecast in Indian agriculture (Rathore *et al.*, 2009; Rathore *et al.*, 2013(a), 2013(b); Chattopadhyay *et al.*, 2016). For example, during 2015-16, entire North Bank plains zone of Assam was affected by the intermittent flash flood during *kharif* 2015 and affected both *Ahu* and *Sali* rice grown in that area. Early season and mid season floods caused not only submergence of the *Ahu/ Sali* rice but also inundation of the vacant field for different period of time and as a result field could not be used for sowing and/ or transplanting *Sali* rice. Thus, different situations (flooding period) were created depending on land situation, soil types and nearness of the crop field to the source of the flood. As a real time response, by using medium range weather forecast, different agro-met advisories were prepared and issued for different flooding situations and disseminated to the farmers of the agro-climatic zone in this region and those farmers used these advisories were immensely benefited by saving the crop loss. In 2015, the village Chamua in Lakhimpur district in Assam recorded exceptionally high rainfall during May (415 mm). Heavy rainfall during May, 2015 affected the maize crop in village Chamua (Fig. 1). The wet spell (50% excess rainfall) occurred in the village affect the maize crop which was in grain filling stage.

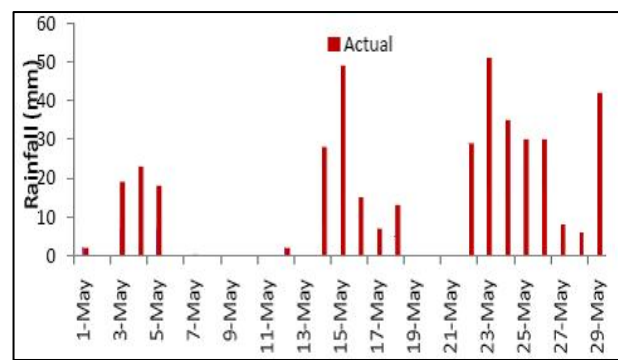**Fig. 1**. Heavy rainfall during May, 2015 affected the maize crop in village Chamua

Fig. 2. Actual rainfall recorded in the village Chamua during May 2015

It was observed that during May, 2015, the actual daily rainfall recorded in the village (Fig. 2) and daily rainfall forecast (for Lakhimpur district) received from IMD was almost matching. Medium range forecast shows that most of the days in May 2015 (Fig. 3) rainfall forecast were issued to the Lakhimpur district. Total rainfall forecast during the entire month for the district is 285 mm. Thus, the rainfall forecast is in consonance with the observed rainfall in one of the Chamua village in Lakhimpur district.

The weather information (weather forecast) available at that time was very much useful in managing the situation arising due to the excess rainfall through real time agro-met advisories. Farmers were benefited with different agro-met advisories issued and displayed in the village.

Following advisories displayed (in different dates during May, 2015 based on the forecast available at that time.

(*i*)   Drain out the water from the fields where maize is grown.
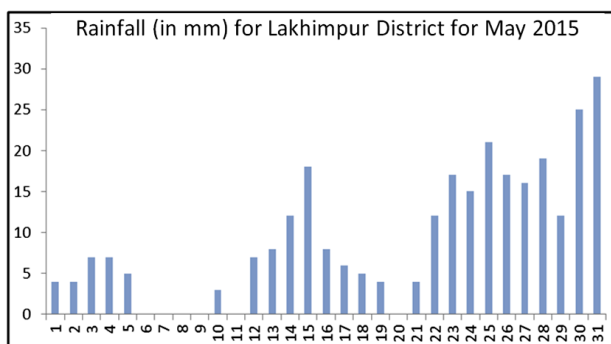
(*ii*)   Harvest the green cobs.

Fig. 3. Medium range weather forecast in May 2015 for Lakhimpur District
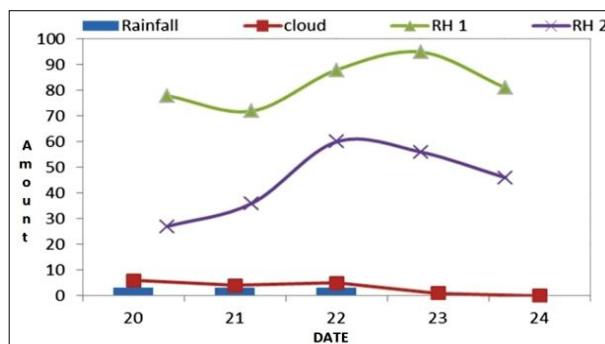

Fig. 5. Medium range weather forecast for rainfall, cloudiness and relative humidity issued on 20th January, 2016 for Lakhimpur district
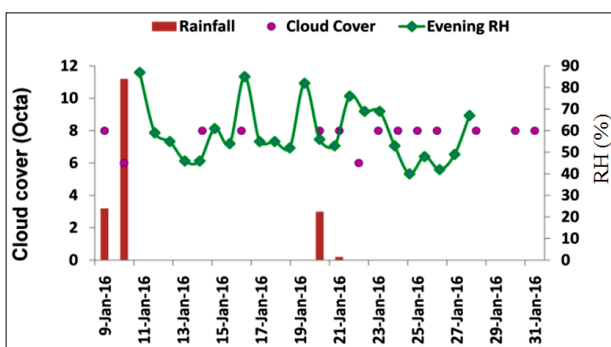

Fig. 4. Daily rainfall, cloudiness and relative humidity recorded at Chamua village, Lakhimpur during 9 to 31 January, 2016

Fig. 6. Impact of Agromet Advisory Services on performance of potato (Variety: Kufri Jyoti) at Chamua, Village, Lakhimpur, Assam 2015-16

(*iii*) If draining out of water from the field is not possible, harvest green cobs and harvest the crops for fodder.

Weather of the Chamua village was exceptional in terms of cloudiness and relative humidity during the month January, 2016. From 9th January to 31st January, 2016 in 14 days cloud was almost overcast and in most of the day's relative humidity varied from 70% to 90%. High humidity and overcast sky along with four rainy days was very favorable for development of late-blight disease in potato and tomato. It was observed that the potato grown in 12 hectare land in the village has been damaged and yield reduction in the tune of 50% is expected. Based on weather forecast available (on overcast sky, high relative humidity and light rainfall (Fig. 4), agro-met advisories were prepared and displayed in the village. Medium range weather forecast issued on 20th January 2016 (Fig. 5) indicates that there is chance of rainfall for next three days including 4-6 okta and also relatively high humidity for next three days. Farmers followed the advisories were benefited (Fig. 6) from agro-met advisories through in increase in the yield potato by 127% (from 9490 to 21563 kg/ ha). It has been reported that there was increase in the yield potato by 127% (from 9490 to 21563 kg/ ha) for the farmers who followed the agro-met advisories (Fig. 6).

Also, a comprehensive third party assessment of socio-economic benefits of Agro-met Services was carried out by reputed National Council of Applied Economic Research [Sharma A. (NCEAR 2015)], Delhi and in their report the Council pointed out that the farming community of the country is using Agro-Meteorological Advisory Service products for critical actions during their farm operations *viz*.,

(*i*) Management of sowing in case of delayed onset of rains;

(*ii*) Shifting to short-duration crop varieties in case of a long-term delay in rainfall;

(*iii*) Deferring of spraying of pesticides for disease control on forecast of occurrence of rainfall in near future;

(*iv*) Managing (curtailing) artificial irrigation in case of heavy rainfall forecast.

The study suggests that the Agro-met Advisory Project of IMD has the potential of generating net economic benefit up to Rs. 3.3 lakh crores on the 4-principal crops alone when Agro-Meteorological
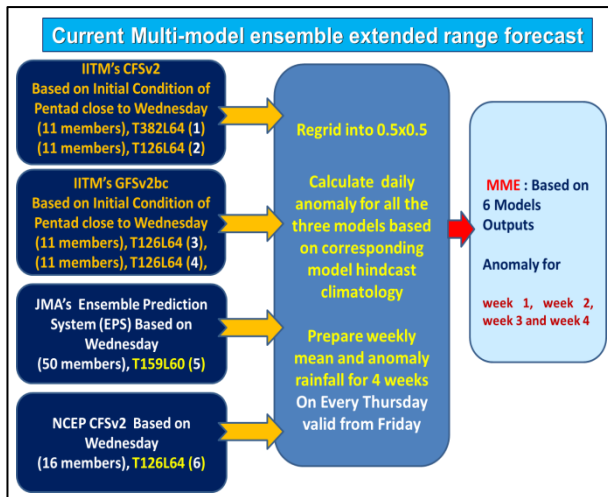
Fig. 7. Schematic flow of extended range weather forecast

Fig. 8. Operational long range forecast issued for southwest monsoon rainfall

advisory Service is fully utilized by 95.4 million agriculture-dependent households. But, there was a need to extend the services to planner's community especially for dry land agriculture planners by advising well in advance (at least 15 days) so as to plan agricultural activities, prepare for contingency. To mitigate this requirement, Agricultural Meteorology Division, IMD, Pune and Indian Institute of Tropical Meteorology, (IITM) jointly started issuing Agro-met Advisory Service bulletin based on Extended Range Weather Forecast (ERWF) bulletin.

Though there has been considerable skill in medium range weather forecast which has already been demonstrated, there was mixed feeling in the skill of sub-seasonal to seasonal forecast in the country. The seasonal drought as well as the unprecedented deficiency of July (>> -51%) rainfall over India during 2002 was not able to forecast by any operational centre. Like 2002, 2009 monsoon season also witnessed large deficiency in seasonal rainfall (>> -22% of long period average). The drought year of 2009 was associated with many dry spells of monsoon and some transition phases of monsoon from weak phases to active phases and vice versa. It was noticed that various climate research centers in India and abroad using statistical and dynamical models could not predict the extent of deficiency of 2009 seasonal monsoon rainfall during June to September. However, a proper real time monitoring of intra-seasonal fluctuation of monsoon rainfall during 2009 monsoon season by IMD was quite useful in assessing the extent and gravity of drought situation of the country (Tyagi and Pattanaik, 2010). Long dry spell of June was very much predicted by the model from the beginning of June (initial condition of 4th June). They have also demonstrated that the dry spells of monsoon during almost the entire June, 1st half of
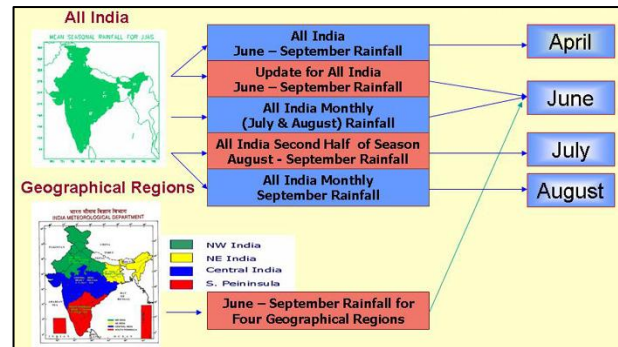
August and 2nd half of September 2009 were well anticipated in the model forecasts, thus, was very useful in the real time forecasting of these dry spells of monsoon 2009. It is not only the agricultural sector which is benefited from the proper outlook of extended range weather forecast (Tyagi and Pattanaik, 2012; Pattanaik *et al*., 2013a; Pattanaik, 2014), a skillful extended range forecast can also be very useful for reservoir operation in reducing floods (Pattanaik and Das, 2015. Acharya *et al*., (2014) studied on comparative evaluation of performances of Climate Forecast System (CFS) models, *i.e.*, CFSv2 and CFSv1 for the southwest monsoon season (June-July-August-September, JJAS) over India with May initial condition during 1982-2009. According to them observed that CFSv2 has improved over CFSv1 in simulating the observed monsoon rainfall climatology and inter annual variability. The overall results suggest that the changes incorporated in CFSv1 through the development of CFSv2 have resulted in an improved prediction of ISMR. As per study of Nageswara rao *et al*., (2016) the updated version of NCEP CFS (CFSv2) having a low index of agreement (0.25) and negative correlation (-0.35) with IMD observation for all India winter (DJF) precipitation, while, the earlier version of NCEP CFS (CFSv1) have high skills of Index of agreement (0.67) and correlation (0.55) values for the same. A number of studies (Stone and Meinke, 2005, Harrison *et al*., 2007, Calanca *et al*., 2011, Hirschi *et al*., 2012, Yan *et al*., 2017) were made in Europe, America, Australia, Africa on the use of monthly and seasonal forecast on pest forecasting, soil moisture availability, drought forecasting etc. and ultimately the crop performance and it has been inferred from these studies that both these forecast have substantial potential to increase the crop production by adopting strategically decision well in time.

The forecast skill of the seasonal monsoon rainfall over India during JJAS in the previous (CFS version1; CFSv1) and new version (CFS version 2; CFSv2) of the NCEP operational systems have been analysed by

Pattanaik and Kumar, 2014, which shows useful skill of monsoon prediction in this time scale. As the large-scale features are better predicted in both CFSv1 and CFSv2 coupled models the hybrid (dynamical-empirical) models for seasonal forecast of monsoon based on the forecast variables of CFSv1 and CFSv2 shows improved skill compared to the actual skill of the model forecasts (Pattanaik and Kumar, 2010).

As there has been considerable improvement of the skill of sub-seasonal to seasonal forecast in recent years, efforts have been made in application of this forecast in agriculture for more crop productivity. In the present paper it has been showed how extended and seasonal forecast performed in taking up strategic decision in agriculture for the farming communities to increase crop production all over the country and also whether the present state of accuracy could be used for generating advisory under contingent crop planning conditions.

2.   Materials and method

Agricultural Meteorology Division, IMD in collaboration with Indian Institute of Tropical Meteorology (IITM), Pune, All India Coordinated Research Project on Agro-Meteorology (AICRPAM), CRIDA, Indian Council of Agricultural Research, Hyderabad prepared Agro-met Advisory fortnightly taking into consideration realized rainfall during previous fortnight and extended range rainfall forecast for next fortnight and crop information, *i.e.*, state and stage of the crops from 2014 to 2016.

For this purpose the group of IITM has indigenously developed Ensemble Prediction system (EPS) based on the state-of-the-art Climate Forecast System Model Version 2 (CFSv2). The EPS generates a large number of forecasts from different initial conditions so that the expected forecast and also the expected spreads or uncertainties in terms of probability from this forecast. Comparison is shown between CFSv2 skill and the atmosphere only GFSv2 model forced with bias corrected SST forecasted from CFSv2. This system uses suite of models at different resolutions *viz.*, (*i*) CFSv2 at T382 (≈ 38 km), (*ii*) CFSv2 at T126 (≈ 100 km), (*iii*) GFSbc (bias corrected SST from CFSv2) at T382 and (*iv*) GFSbc at T126. This dynamical prediction system developed at IITM has been transferred to IMD and the same has been implemented by IMD for generating operational ERWF products to different users.

For the operational run at IMD, the Atmospheric (initial condition ICs) are obtained from the National Centre for Medium Range Weather Forecast (NCMRWF)

and the oceanic ICs are used from National Centre for Environmental Prediction (NCEP). The suite of models are integrated for 32 days based on every Thursday initial condition with 4 ensemble members (one control and 3 perturbed) each for CFSv2T382, CFSv2T126, GFSbcT382 and GFSbcT126. The same suites of model are also run on hindcast mode for 10 years (2001-2010). The average ensemble forecast anomaly of all the 4 set of model runs of 4 members each is calculated by subtracting corresponding 10 years model hindcast climatology. For the preparation of mean and anomaly forecast on every Thursday, which is valid for 4 weeks for days 2-8 (week1; Friday to Thursday), days 09-15 (week2; Friday to Thursday), days 16-22 (week3; Friday to Thursday) and days 23-29 (week4; Friday to Thursday). Current flow of extended range weather forecast is given in Fig. 7 in the schematic format.

As far as the seasonal forecast is concerned outputs from both statistical and dynamical models have been used in the present study. The forecast for the South-West monsoon rainfall is issued in April and June. Fig. 8 shows the Operational Long Range Forecast issued for South West monsoon rainfall. From 2007, a new statistical forecasting system is used, which is based on the ensemble technique involving 8 predictors. In the ensemble method, all possible models based on all the combination of predictors are considered. Thus, for April (June) forecast, with 5 (6) predictors, 31 (63) different models were developed. Out of all the possible models, ensemble mean of the best few models were selected based on their skill in predicting monsoon rainfall during a common period. The weights are proportional to the multiple correlation coefficients of the models during the training period. For developing the models, two different statistical techniques namely, Multiple Regression (MR) and Projection Pursuit Regression (PPR) were considered. Since 2004, ESSO-IMD has been generating experimental dynamical forecast for the southwest monsoon rainfall using the seasonal forecast model (SFM) of the Experimental Climate Prediction Center (ECPC), USA. For generating the forecasts, ten ensemble member forecasts were obtained using the initial conditions corresponding to 0000 UTC from 1st to 10th of each month on which the forecast was prepared.

3.   Results and discussion

Application of extended range forecast has been started from the year 2014 on pilot mode. In the year 2015 and 2016, it was made on operational mode. For that period, usability of forecast and its applications in different parts of the country in agricultural planning was tested. Feedback has been taken from diverse sources like Agricultural Universities including farmers. Some of the
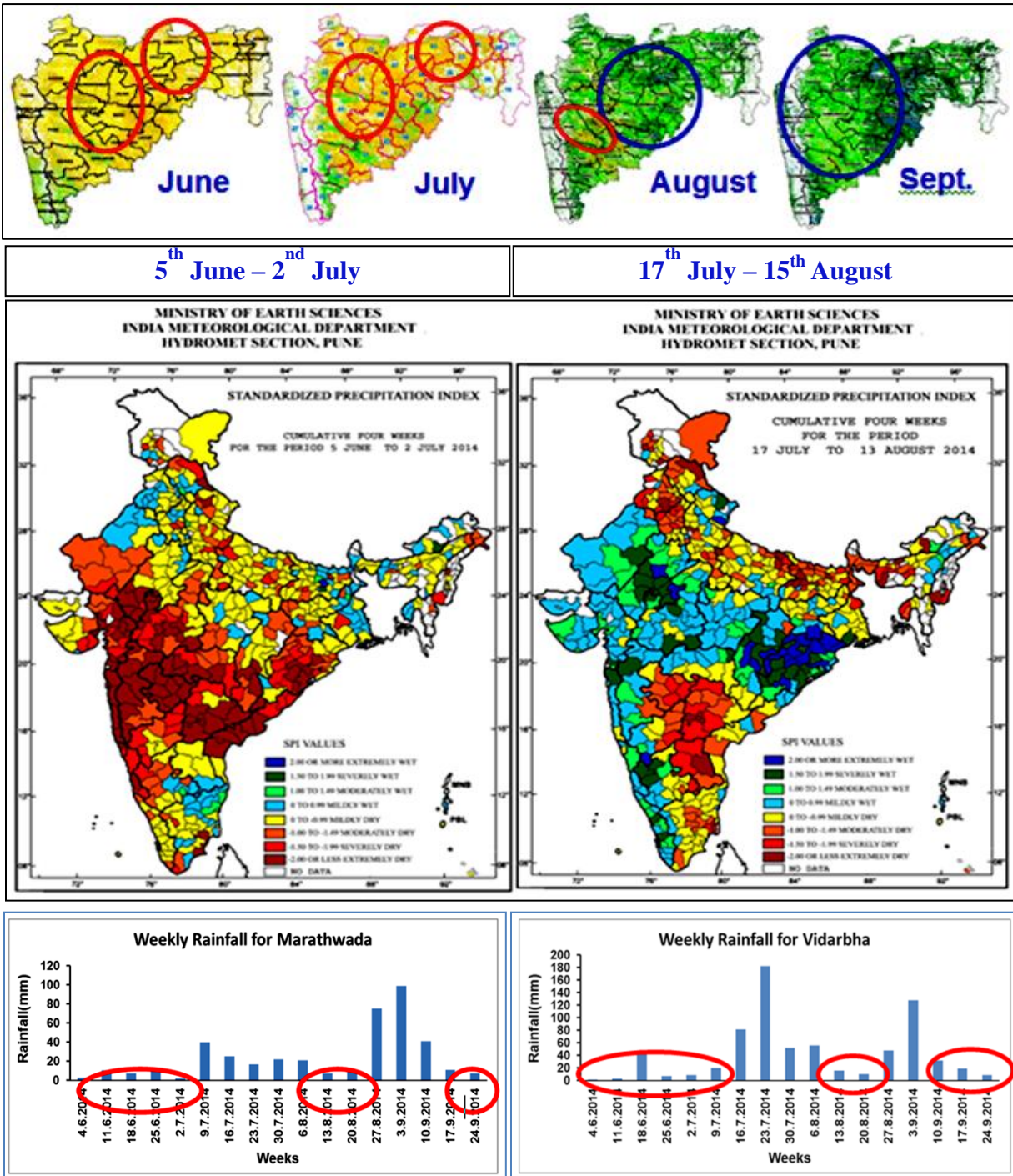
Fig. 9. Poor rainfall situation in June and July 2014 for Marathwada and Vidarbha

case studies have also presented here to evaluate the forecast and its use in agricultural system.

During the experimental period in the monsoon season from June to September 2014, it has been noticed that drought like situation was prevailed in Madhya Maharashtra, Marathwada and Vidarbha regions of

Maharashtra. This was captured well in the extended range weather forecast and "Contingency crop planning was given for Marathwada and Vidarbha as follows":

For Madhya Maharashtra instead of normal crops like sunflower, soyabean, cotton, hybrid jowar, hybrid

For flood free areas	Pest	• Sunny days/ high temperature after continuous and heavy rainfall for long period (1 to 2 weeks) during August is very conducive for heavy infestation of rice (which is at tillering stage) with *Rice Hispa*. Therefore farmrers are advices to be ready for tackling the situation. • Rice hispa along with other insects like leaf folder, case worm etc can be controlled by spraying with Chloropyriphos 20EC or Monocrotophos 40EC @ 1.5ml per liter of water. • It is advised to spary recommended insecticides when there is one damage leaf per hill due to attack of leaf folder or appearance of one adult hispa per hill is observed.
Pulses	Sowing	• Prepare land to sow seeds of green gram and black gram. Select high lands having sandy-loam textures for the crop. The recommended varieties of green gram are T-44, Kopergaon, K-851, ML-56, ML-131 etc. Recommended varieties of black gram are T-9, T-27, Pant U-19, T-122.

Fig. 10(a). Advisories issued on 2nd August, 2016

Fig. 10(b). View of rice field at Narayanpur, Lakhimpur during 2016

pearl millet, red gram and sesame, it was advised to adopt contingency plan, *i.e*., intercropping of - pearlmillet + redgram, sunflower + redgram, soyabean + redgram, guar + redgram. For Marathwada the districts to be affected were Aurangabad, Beed, Jalna, Osnamabad, Parbhani, Hingoli, Nanded, Latur. The normal crops grown in this region are cotton, soyabean, red/ black gram, sorghum, sunflower, sugarcane. Contingency given for inter-cropping of cotton + pigeon pea, pigeon pea + sunflower or bajra and also for short duration varieties of soyabean.

In Vidarbha, the districts to be affected were Buldhana, Chandrapur, Yeotmal. The normal crops grown in this region are Bt. Cotton and in eastern parts of Vidarbha, it is rice. Contingency were given for American cotton/ Desi cotton and intercropping in western Vidarbha region. For intercropping cotton+sorghum+pigeonpea+ sorghum, short duration pigeonpea and also intercropping of sorghum with pigeonpea were advised. In eastern Vidarbha, contingency for direct sowing of early maturing & mid late maturing rice varieties by wet seeding method were given. The farmers in this region follow the same and also benefited by the agro-met advisories provided to them. This has been shown schematically in Fig. 9.

Similarly in 2015, using the ERWF based contingency was given for dry regions of North Interior

Karnataka, Rayalseema and Telangana. In North Interior Karnataka, number of contingency plans were advised like sowing of fodder crops on preference sowing of niger, foxtail millet (PSC-1, RS-118), mataki , horse gram (PHG-9, KBH-1), castor as well as intercropping of pearl millet + pigeon pea (2:1), pigeon pea + sesame (1:2 or 2:4), bajra + castor (2:1) in light and medium black soils and bajra, pigeon pea, castor, chilli, sesame, foxtail millet, onion, bajra + castor (2:1), fodder crops in medium black soils after receipt of sufficient rain. In Telangana, instead of cotton, redg ram, jowar, sowing of sole red gram (Maruti, Lakshmi, PRG 158 etc.) adopting closer spacing of 90 x 30 cm. And in Rayalaseema sowing of red gram (PRG-158, Asha, LRG-41), castor (PCH-111, PCH-222, Kranti, GCH-4, Haritha) and rain-fed groundnut (Kadiri-6, Kadiri-9, Narayani and dharani) in Anantapur district after receipt of sufficient rain, Sowing of contingent crops like pearl millet, cowpea, green gram, sunflower (Morden) were also advised.

Though the agro-met advisories based on the ERWF were issued to the different parts of the country, verification of the same has been made in Assam state particularly on sowing of rice on pre-monsoon season and pest and diseases incidences on rice. Two case studies on verification of ERWF are illustrated as follows:

3.1. *Case study of pest attack based on ERWF*

In August 2016, deficit of rainfall was forecasted over Assam region. The expected weather condition was favourable for building up insect *rice hispa* population in *Sali* rice after the continuous rainfall during July/ (early August) followed by sunny days with high temperature and high humidity during August. Insect infestation is usually found maximum in the early tillering stage of *Sali* rice. Due to occurrence of flood during July, transplanting was delayed and paddy in those flood affected areas will be in the early tillering stage during August/ September. Under the situation of occurrence of dry spells during August/ September (after long wet spell), delayed transplanted crops are to be affected more as compared to the July transplanted paddy. Therefore, following advisories were issued on 2nd August, 2016 [Fig. 10 (a)]. View of rice field at Narayanpur, Lakhimpur during 2016 is given in Fig. 10 (b).

Based on ERWF normal to above normal rainfall forecast (Fig. 11) were issued over Assam region during July and early August followed by deficient rainfall in the next half of August. As per the realized rainfall maps of July and August 2016 (Fig. 12), it is seen that good rainfall occurred in July to the early part of August followed by dry spells. Thus the forecast is well in agreement with the realized rainfall. The realized weather
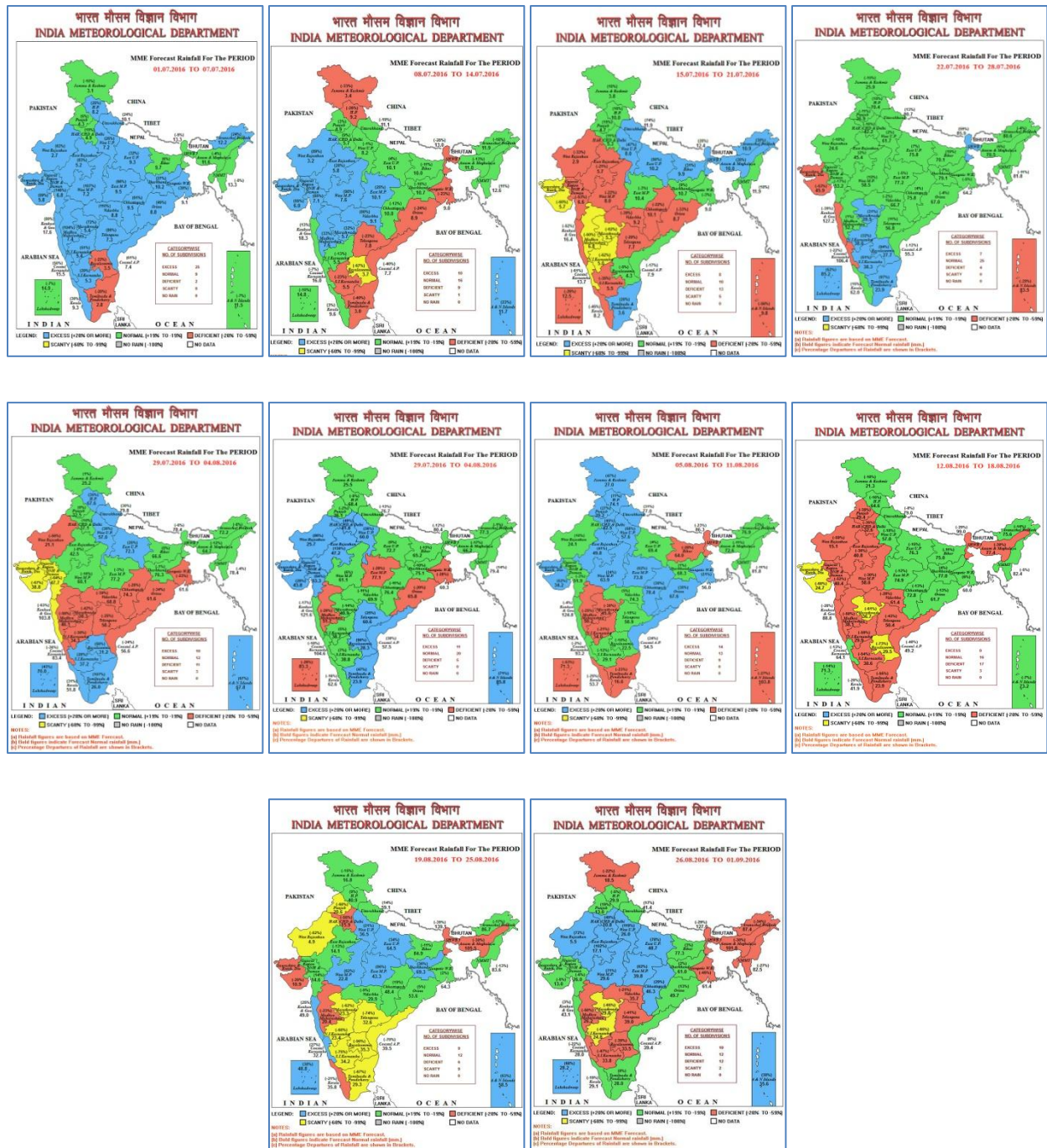
Fig. 11. ERWF for rainfall for July and August 2016

condition was favourable for attack of pest on *Sali* rice. Based on the weather forecast farmers were advised for taking prophylactive measures for controlling the pest. (Advisories for pest are shown above). Farmers those followed the agro-met advisories were benefited by avoiding the loss due to *rice hispa* infestation on *Sali* rice.

3.2. *Case study on sowing of rice based on ERWF*

In Ganokdoloni village of Lakhimpur district of Assam during 2014-15, the yield of all *bao* varieties grown in the village was reduced substantially as compared to the earlier season (2013-14), which was due
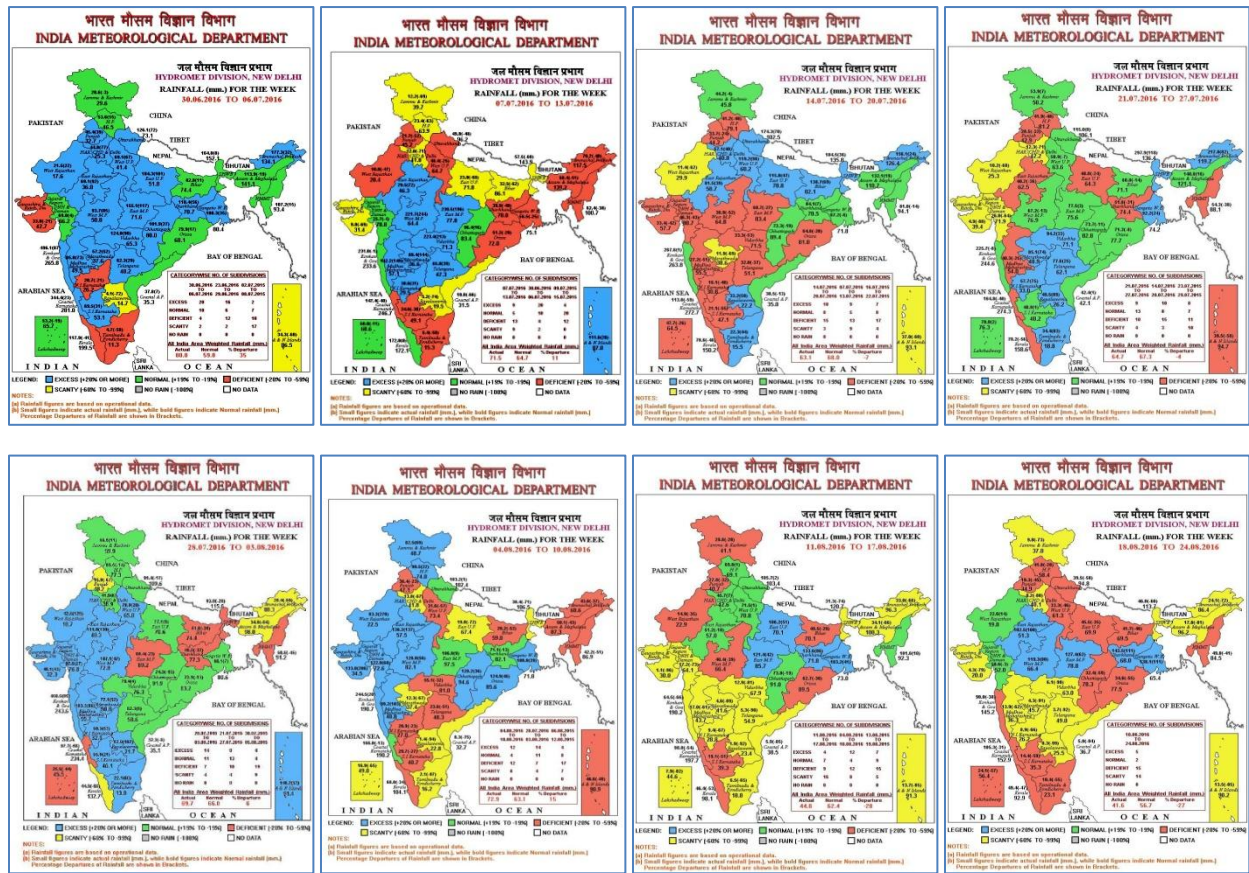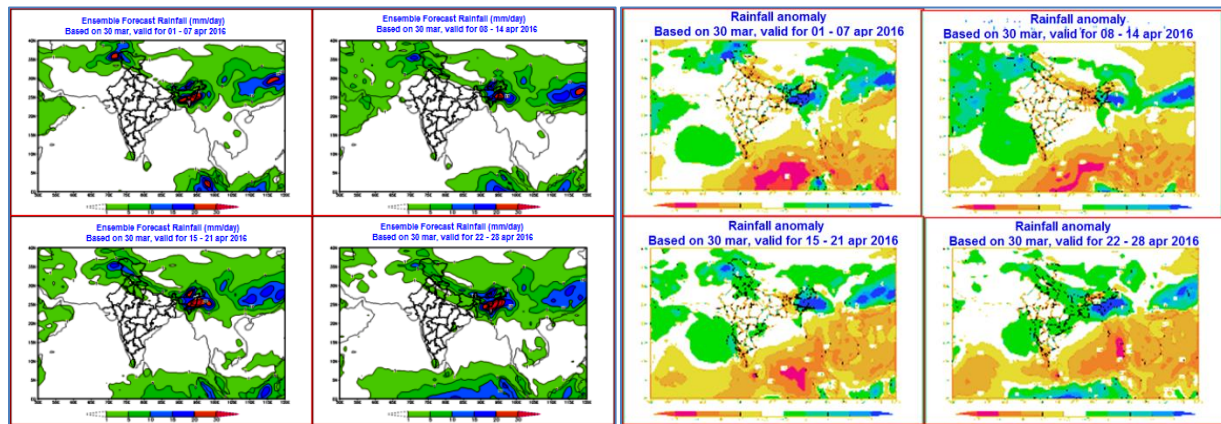
Fig. 12. Realised rainfall for July and August 2016

Figs. 13 (a & b). (a) ERWF rainfall forecast, IC 30 MAR, 2016, (1-28 April, 2016), (b) ERWF rainfall anomaly, IC 30 March, 2016, (1-28 April, 2016)

to exposure of the crop to severe moisture stress at the seedling stage (March to May), as the village was experienced with long dry spell from 24th November, 2014 to the first week of May, 2015.

Thus, the farmers in this village had lot of confusion to start sowing of *bao* rice in 2016. Up to 30th March,

2016, farmers of the village did not start sowing of *bao* varieties. Based on the forecast of continuous rainfall during April, 2016 received from IMD, farmers were advised to complete the sowing as early as possible (within first/ second week of April). Though, the situation of the village was worse than the previous year, due to more rainfall during April and May farmers were able to
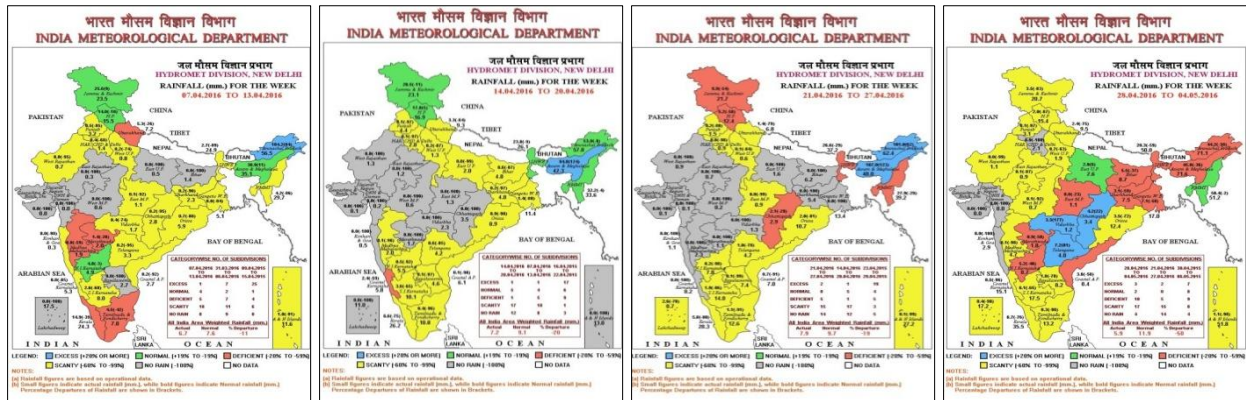
Fig. 14. Realised rainfall in April 2016

complete the sowing. Thus, the advisory given based on extended weather forecast was proved to very useful for the farmers of the village. In this village during 2016-17, extended rainfall forecast of IMD was well utilized for issuing useful advisories to the farmers of the village. [Figs. 13 (a&b)] : MME mean rainfall and anomaly; IC 30th March, 2016, (1-28 April 2016) respectively and also Fig. 14 shows realised rainfall in April 2016.

Besides, feedback on the use of ERWF in agriculture received from number of Agro-met Field Units and the farmers across the country are given below:

3.2.1. *Feedback from various Agro-met Field Units*

(*i*)   The AMFU, Hyderabad has prepared agro-met advisories using Extended Range Weather Forecast in both *kharif* and *rabi* seasons and mentioned that the ERWF could be effectively used in the preparation of agro-met advisories on various agricultural operations like land preparation, sowing, harvesting, fertilizer application, irrigation scheduling and application of insecticides/ pesticides the above operations.

(*ii*)   AMFU, New Delhi has mentioned that the ERWF is useful for management of input and planning for agricultural operations.

(*iii*) AMFU, Coimbatore using the forecast for various decisions like time of sowing, variety of crops to be sown and method of cultivation, management of inputs like seeds, fertilizers and other bio-inoculant, harvesting and storage of output. The AMFU has mentioned the need of using ERWF in crop models for deciding the management strategies. They have also stressed on the analysis of economic impact of SCF information.

(*iv*)   AMFU, Pantnagar has stated that ERWF was found to be useful in decision on various farm operations like selection of land/ crops, planning irrigation and for adopting plant protection measures. Extended range forecast found to be of great importance for agricultural planning (sowing, harvesting, etc.), which can enable tactical adjustments to the strategic decisions that are made based on the longer-lead seasonal forecasts and also help in timely review of the ongoing monsoon conditions for providing outlooks to farmers.

(*v*)   AMFU, Lamphelpat has stated that the information provided to us in the extended weather forecast from IMD is very helpful for better guidance and knowledge in preparing the agro-met advisories for farmers. The accuracy in giving weather forecast has increased with the use of the additional information from the extended weather forecast especially on extreme weather, temperatures and rainfall along with the past days weather information.

After issuing district level agro-met advisories to the farmers by using ERWF, farmers are benefitted and given their feedback which is as follows:

3.2.2. *Feedback from farmers*

(*i*) *Farmer : Mr. Matti, Dharwad, North Interior Karnataka*

ERWF was given (16th September, 2015) that "Rainfall to revive in the last week of September" and advisories were to prepare for harvest of crop after rainfall (Groundnut). Modified ERWF conveyed in the third week of September that rainfall to revive from 1st October. Used this gap of four days for ploughing of fields for sowing of *rabi* crops.
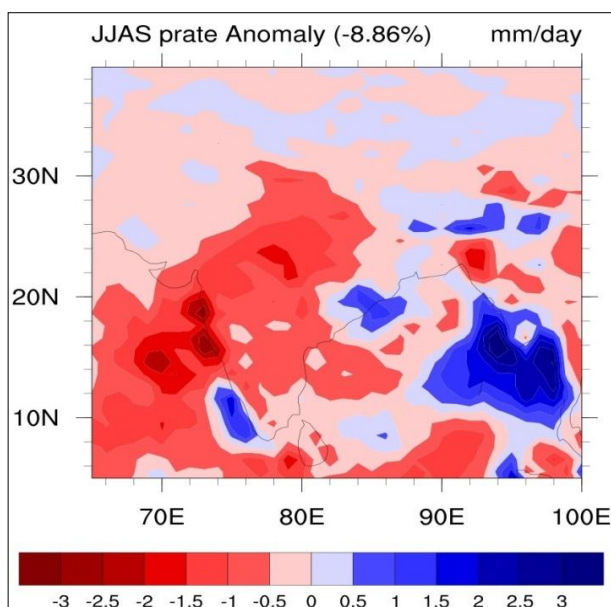
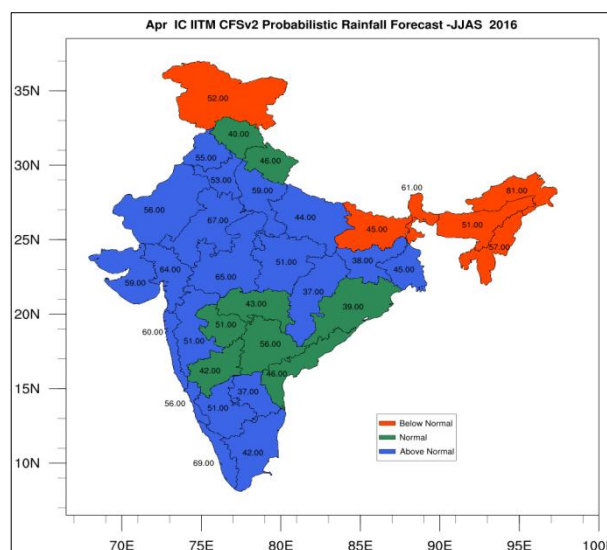**Fig. 15**. IITM CFS2 T382 rainfall anomaly forecast: 2015 JJAS

Fig. 16 (a). IITM/IMD CFSv2 T382 probabilistic rainfall

Fig. 16 (b). IITM/IMD CFSv2 T382 rainfall % departure

(*ii*) *Farmer: Mr. Anand Joshi, Vijayapura, Bijapur, North Interior Karnataka*

As per extended range forecast on 15th August, 2015, rainfall was expected in the last week of August. Farmer planned to take up sowing of sunflower. Land preparation also made. In modified ERWF on 22nd August, 2015 rainfall during 4-13 September expected not August end", farmer cancelled sunflower sowing. He revised the plan for sowing of sorghum and chickpea. On 5th September rainfall received and he sown sorghum and chickpea.

For horticulture crops also, as per ERWF on 16th September, 2015, rainfall was expected in the last week of September and early October. Farmer decided not to take up grape-pruning during September to avoid downy mildew disease. 80% of Grape orchards pruned in September are affected by disease due to rain in first week of October.

In KVK, Vijayapura (Bijapur), extended range forecast was given on 28th August, 2015 that "expected rainfall during 4-13 September". Farmers planned for Sorghum, chickpea and safflower seed production / general. Land preparation was made. Seed were procured and treated. Sowing performed (10 -24 September) after rainfall on 5th September, 2015 (Sorghum : 10 acres/ 3000 ha, Chickpea : 12 acres/ 5000 ha, Safflower (A-1 variety): 500 ha). No rainfall after second week of September to till 1st week of October, 2015.
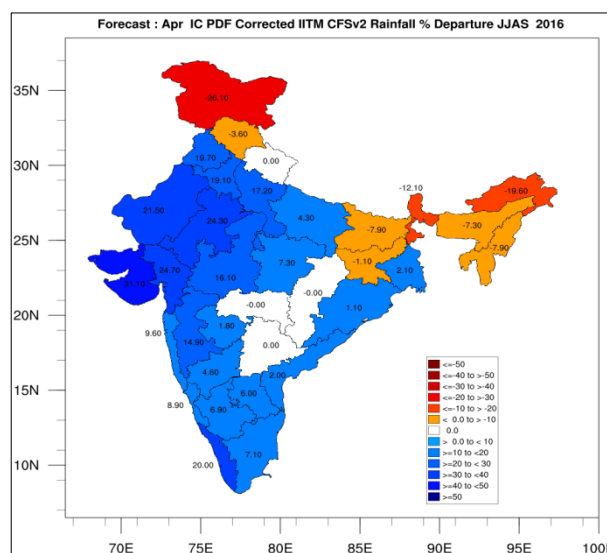
3.3. *Agro-met advisories based on seasonal weather forecasts*

As far as the seasonal forecast is concerned, seasonal forecast for the country as a whole and four homogeneous regions of the country is made using statistical models and also 3 categories had been made i.e. states falling under excess rainfall, below normal rainfall and normal rainfall from dynamical models which are being used in generating the agro-met advisories for strategic planning. On an experimental basis IMD in collaboration with Central Research Institute for Dry-land Agriculture (CRIDA) has started to prepare agro-met advisory
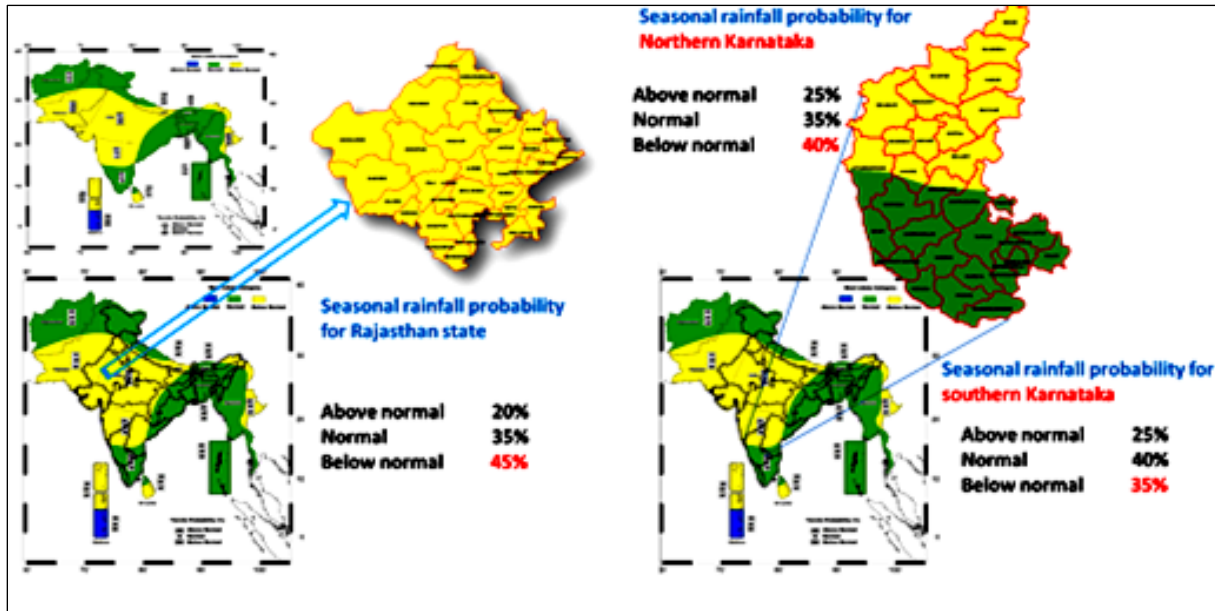
Fig. 17. Seasonal rainfall forecast which has been overlaid by district map for Rajasthan and Karnataka

particularly in the states where prolonged dry spells and floods are expected during the monsoon season. Through these advisories a general outlook has been provided for taking appropriate strategies of input management in respect of making arrangement for seeds for short and medium duration alternate crops, fertilizers, pesticides, water harvesting etc. based on the projections of rainfall of different temporal scale.

In 2015, IMD, Ministry of Earth Sciences (MoES) issued its official forecast in April for the performance of seasonal rainfall over the country as a whole during the monsoon season from June to September (JJAS). The forecast indicates below normal rainfall for the country as a whole with a quantitative value of 93% of its long period average with a model error of ± 5%. Considering the four broad geographical regions of India, the forecasts issued in June for the season rainfall over northwest India, Central India, northeast India and south Peninsula were 85%, 90%, 90% and 92% of the LPA respectively all with model errors of ± 8%. Besides, the experimental dynamical seasonal rainfall forecast during JJAS 2015 based on the coupled model CFSv2 run at MoES-IITM, Pune indicates below normal rainfall over many parts of India (Fig. 15). There is indication of below normal rainfall over Uttar Pradesh, East Rajasthan, Madhya Pradesh, Gujarat, Marathwada, Interior Karnataka, Telangana, Rayalaseema and Coastal Andhra Pradesh. Remaining subdivisions was expected to experience normal or above normal rainfall.

Based on operational and experimental rainfall forecast as mentioned above, there is need for preparedness for adaption of contingency planning for the farmers to combat the situations in the above mentioned states where deficient rainfall is expected during *kharif* season. There is chance of failure of normal crop cultivation under such stress condition. In the deficient rainfall subdivisions, strategies for arrangement of readily available medium and short duration normal crops and alternate crops with specific varieties, as mentioned in detail, for different sub-divisions need to be taken up at the earliest. Contingency planning was also issued for the states Rajasthan, Madhya Pradesh Andhra Pradesh, Gujarat and Maharashtra.

Similarly in 2016, IMD/ (MoES) issued its official forecast in June, 2016 for the performance of seasonal rainfall over the country as a whole during the monsoon season from June to September (JJAS). The forecast indicates above normal rainfall for the country as a whole with a quantitative value of 106% of its long period average with a model error of ± 5%. Region wise, the season rainfall is likely to be 108% of LPA over North-West India, 113% of LPA over Central India, 113% of LPA over South Peninsula and 94% of LPA over North-East India all with a model error of ± 8%. The monthly rainfall over the country as whole is likely to be 107% of its LPA during July and 104% of LPA during August both with a model error of ± 9%. The experimental seasonal rainfall forecast is given in Fig. 16 (a & b) during JJAS(June to September) 2016 based on the

TABLE 1

Crop Situation in Andhra Pradesh (Kharif-2015)

District	Actual area sown in Kharif (ha)		Original crop in the area
	2015	Normal	
Bajra			
Kurnool	8273	7095	Cotton, Castor, Rice
YSR Kadapa	2377	2035	Rice
Chittoor	2403	2134	Groundnut
Anantapur	2421	1782	Groundnut
Blackgram			
Guntur	1066	359	Cotton, Rice
Prakasam	5181	1466	Cotton, Rice
Kadapa	1279	327	Rice
Greengram			
Anantapur	12380	618	Groundnut
YSR Kadapa	2069	342	Rice
Redgram			
Prakasam	67103	54038	Cotton & Rice
Guntur	19560	15351	Cotton & Rice
Rayalseema district	1200	1200	
Horsegram			
Anantapur	6280	1614	Groundnut
Chittoor	5892	1642	Groundnut
Kadapa	1227	78	Rice
Coarse cereals & Miner millets			
Kurnool	29000	20000	Cotton, Castor & Rice
Kurnool	19519		Cotton, Castor & Rice

coupled model CFSv2 run at MoES-IITM, Pune. It indicates that:

(*i*) There is chance of below normal rainfall especially over Jammu & Kashmir, Bihar, Arunachal Pradesh, Jharkhand, Uttarakhand, Sub-Himalayan West Bengal & Sikkim, Assam & Meghalaya, Nagaland, Manipur Mizoram & Tripura.

(*ii*) Above normal rainfall is also likely to occur over West Rajasthan, East Rajasthan, Saurashtra & Kutch, Kerala, Haryana, Chandigarh, Delhi, Punjab during the season.

(*iii*) Normal rainfall is expected on remaining part of the country. Cultivation of normal cropping pattern is likely to be expected over these regions.

Based on operational and experimental rainfall forecast as mentioned above, there is need for preparedness for adaption of contingency planning for the farmers to combat the situations in those states where deficient/ excess rainfall is expected during *kharif* season. There is chance of failure of normal

crop cultivation under such stress condition. The probable deficient rainfall in those subdivisions, strategies for arrangement of readily available medium & short duration normal crops and alternate crops with specific varieties, as mentioned in detail, for different subdivisions need to be taken up at the earliest. Besides, contingencies under heavy rainfall/ flood like situations have also been mentioned. Contingency plan has been planned keeping in view four categories of drought conditions, namely delayed onset of monsoon, early season drought, mid season drought and terminal drought.

Advisories for mitigation of drought like situations the advisories were given as bunding of fields should be done to conserve and retention of water. Gap filling, weeding or intercultural operations should be done. Give life saving irrigation during critical growth stages if possible. Follow water conservation, mulching and conservation tillage and other management practices. Thinning, spraying of anti transparent, alternate wetting and drying upto primordial initiation stage may be done to save water. In rice, keep seedlings ready for transplanting upto 45 days. To boost the early vegetative growth of

TABLE 2

All India crop situation-Kharif (2015-2016)

Crop name	Normal area for whole kharif season	Normal area as on date	Area sown reported			Absolute change (+/-) (In lakh hectares)	
			This year 2015	% of normal for whole season	Last year 2014	Normal as on date	Last year
Rice	388.34	281.31	277.89	71.6	265.90	-3.4	12.0
Jowar	27.27	21.01	16.76	61.5	14.73	-4.3	-2.0
Bajra	84.80	64.28	63.16	74.5	52.25	-1.1	10.9
Maize	72.50	68.67	70.36	97.0	66.69	1.7	3.7
Total coarse cereals	204.41	164.93	158.62	77.6	141.43	-6.3	17.2
Total cereals	592.75	446.24	436.51	73.6	407.33	-9.7	29.2
Tur	39.28	33.14	29.82	75.9	30.24	-3.3	-0.4
Urad	23.78	19.76	23.56	99.1	20.19	3.8	3.4
Moong	24.46	20.66	21.24	86.8	17.71	0.6	3.5
Kulthi	2.67	0.21	0.25	9.2	0.27	0.0	0.0
Others	18.56	15.23	17.77	95.8	12.83	2.5	4.9
Total pulses	108.75	89.00	92.68	85.2	81.24	3.6	11.4
Total food grains	701.50	535.24	529.15	75.4	488.57	-6.1	40.6
Groundnut	44.97	36.37	31.06	69.1	32.36	-5.3	-1.3
Soyabean	104.00	103.18	110.71	106.4	104.2	7.5	6.7
Sunflower	3.39	1.57	0.65	19.2	1.35	-0.9	-0.7
Sesamum	18.62	11.12	12.99	69.8	11.81	1.9	1.2
Nigerseed	3.44	0.69	0.55	16.0	0.43	-0.1	0.1
Castorseed	10.77	3.45	1.47	13.6	2.35	-2.0	-0.9
Total oilseeds	185.19	156.38	157.43	85.00	152.31	1.1	5.1
Cotton	114.96	109.95	105.68	91.9	112.24	-4.3	-6.6
Sugarcane	48.18	49.44	47.36	98.3	47.17	-2.1	0.2
Jute and Mesta	8.77	8.41	7.79	88.9	8.11	-0.6	-0.3
All crops	1058.59	859.41	847.40	80.0	808.40	-12.0	39.0

crop, enhanced basal dose of NPK or apply organic manure wherever possible.

Also in the above normal rainfall occurring states namely West Rajasthan, East Rajasthan, Gujarat, Saurashtra, Kutch & Diu, Kerala, the measures to combat such situations were given like apply sub-surface drainage system, maintain proper drainage and drain out the excess water, apply soil nutrient, spray of nutrients supplementation and conservation excess rain water for future use. Maintaining the soil in sub-saturated condition and prefer varieties or crops which are water logging resistant and having seed dormancy. If heavy rainfall

occurs in early crop growth stage then re-sowing of crop or alternate crops are recommended while if heavy rainfall occurs in late growing stage then crops may be harvesting at physiological maturity. Also in rice growing areas it is advised to keep rice nurseries upto 40-45 days for re-sowing.

Thus on the basis of projected rainfall for monsoon 2016, the Department of Agriculture (Centre, New Delhi and States) need to prepare strategies along with the specific contingency plan for above mentioned regions to make the seeds of the alternate varieties and alternate crops available, so that the same

may be provided to the farmers under adverse rainfall situation.

Besides, under the South Asian Climate Outlook Forum (SASCOF) initiatives, a consensus outlook for 2016 Southwest monsoon season rainfall over South Asia was prepared based on the expert assessment of prevailing large-scale global climate indicators as well as operational long-range forecasts based on statistical and dynamical models generated by various operational and Research centres of the world.

In order to generate agro-met advisories for strategic planning, seasonal rainfall forecast has been overlaid by district map to generate and preparation of state rainfall probability maps for e.g., Rajasthan and Karnataka State given in Fig. 17. State wise rainfall probability maps are generated and shared with state government authorities. Good appreciation was received from state level authorities. If the month wise distribution on spatial scale is available with probabilities, district wise better planning could be made with reference to contingencies that need to be initiated. Also, as per the seasonal forecast, advisories issued for the farmers on sowing short-duration, less water requiring crops, such as pulses were followed by farmers in a big way. Due the prior forecast, farmers were benefited and the crop sown area was also increase in Andhra Pradesh for the year 2015 for the crops Black gram, Green gram, Red gram, Horse gram, Coarse cereals and Miner millets which is given in Table 1. The area under contingent crops increased significantly. Also at all India level crop sowing area Maize, Urad, Total pulses, Ses ame, total oilseeds has been increased which is given in Table 2.

4. Conclusions

With the rapid advances in Information Communication Technology (ICT) and its spread to rural areas, the demand for provision of timely and accurate weather forecasts for farmers is increasing very fast. It has been established with fair degree of accuracy that Agro-met Advisory Services based on medium range forecast valid for next 5 days is able to help the farming community of India to perform the agricultural activities in prevailing weather conditions and to minimize the impact of adverse weather conditions (heat wave, cold wave, heavy rainfall, flood, cyclones, hailstorm etc.) on crops and ultimately boost agricultural production. Like medium range weather forecast, usefulness of extended and seasonal weather forecast enables farmers to organize and carry out appropriate cultural operations to cope with or take advantage of the

forecasted weather is warranted. Also it is useful for strategic planning of farm operations. Weather forecast at higher spatial resolution with reasonable accuracy is important to enhance adoption level. Monthly forecasts with possible weekly distribution are more helpful for crop stage specific management. Though in the present study usefulness of extended range and seasonal forecast could be demonstrated with some case studies, more studies are required in these areas in different agro-climatic zones in the country to assess the skill of these forecast as well as usability of the same in agriculture in the country.

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