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Validation of medium range weather forecasts and its economic impact on cotton-wheat cropping system in South-Western Punjab

RAMALPREET SINGH, R. K. PAL, K. K. GILL*, S. K. MISHRA** and ANUREET KAUR***

Department of Climate Change and Agricultural Meteorology, Ludhiana – 141 004, Punjab, India

**Communication Centre, Punjab Agricultural University, Ludhiana – 151 203, Punjab, India*

***Punjab Agricultural University, Regional Research Station, Faridkot – 151 203, Punjab, India*

****Punjab Agricultural University, Regional Research Station, Bathinda – 151 001, Punjab, India*

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e mail : rkpal1985@pau.edu

सार – 2013-14 **से** 2017-18 **के दौरान पंजाब के बठिंडा और फरीदकोट, जिलों के कृषि-मौसम विज्ञान वेधशालाओं से लिए गए वास्तविक डेटा का उपयोग करके मौसम विज्ञान केंद्र, चंडीगढ़ से प्राप्त वर्धित मान के मध्य अवधि मौसम पूर्वानुमान की पुष्टि की गयी। इसके अलावा, पूर्वानुमान के आर्थिक प्रभाव का अध्ययन करने के लिए,** 2016-17 **में रबी के दौरान गेहूं और खरीफ** 2017 **के दौरान कपास पर बुवाई के दो समय और दो प्रबंधन स्तरों आदि चार प्रतिकृतियों के लिए कृषि मौसम सलाहकार सेवाओं को अपनाने और नहीं अपनाने के लिए प्रयोग किए गए। परिणाम से पता चला कि वर्षों और ऋतुओं में वर्षा पूर्वानुमान में अधिकतम सटीकता पाई गई, जबकि पवन की गति के पूर्वानुमान में सबसे कम सटीकता देखी गई। तापमान को छोड़कर, सभी मौसम प्रचालों के लिए मानसून पूर्व ऋतु के दौरान उच्च सटीकता प्रेक्षित की गई। वैकल्पिक रूप से, अध्ययन स्थानों में वर्षा, मेघावरण, अधिकतम तापमान, न्यूनतम तापमान और पवन की गति के पूर्वानुमान की मौसमी उपयोगिता क्रमशः** 87-98%, 65-75%, 51-72%, 56-67% 44-83% **के बीच सफलता पाई गई, जबकि पूर्व प्रयोज्यता क्रमशः** 93-96%, 63-73%, 45-70%, 56-70% **और** 35-87% **थी। इसके अलावा, अध्ययन स्थानों में, पूरे वर्ष आरएमएसई को** 3.95-5.12 **मिमी,** 2.71-2.80 **ओक्टा,** 2.83-2.85 **डिग्री सेल्सियस,** 2.39-2.51 **डिग्री सेल्सियस और** 5.79-7.47 **किमी प्रति घंटे की सीमा में प्रेक्षित किया गया, जबकि वर्षा, मेघावरण, अधिकतम तापमान, न्यूनतम तापमान और पवन की गति के संबंध में सहसंबंध गुणांक का मान क्रमशः** 0.68-0.83, 0.39-0.44, 0.92-0.93, 0.95-0.96 **और** 0.35-0.43 **के बीच रहा। इसके अलावा, अपनाई गई कृषि-मौसम संबंधी सलाहकार सेवाएं (एएएस) मूल्यवान पाई गईं, जिसमें फसलों और अध्ययन स्थानों दोनों फसलों के लिए गैर-अपनाए गए एएएस पर बेहतर उपज और इसकी विशेषताओं को देखा गया। इसके अलावा, कृषि-मौसम संबंधी सलाहकार सेवाओं का समय पर अनुपालन और विलम्ब से बुवाई करने से क्रमानुसार कपास की उपज में प्रति एकड रुपये** 4055/- **तथा** 1900/- **रु. का अतिरिक्त लाभ और गेहूं की उपज में रु.** 5461/- **तथा** 5045/- **रु. का अतिरिक्त लाभ हुआ । वहीं दूसरी ओर कृषि-मौसम संबंधी सलाहकार सेवाओं को अपनाकर समय पर और विलम्ब से बुवाई करने से कपास की उपज में** 17% **तथा** 21% **का और गेंहू की उपज में** 26% **एवं** 18% **का शुद्ध लाभ हुआ।**

ABSTRACT. The value-added medium range weather forecast, received from Meteorological Centre, Chandigarh was validated using actual data taken from Agro-meteorological observatories of Bathinda and Faridkot, districts of Punjab during 2013-14 to 2017-18. Moreover, to study the economic impact of the forecast, field experiments were conducted during Rabi 2016-17 on wheat and Kharif 2017 on cotton having two sowing time and two management levels as adoption and non-adoption of agromet advisory services with four replications. Result revealed that, among the years and seasons, maximum accuracy was found with rainfall forecast, while, least correctness of the forecast was observed with wind speed. Except temperature, higher accuracy was observed during pre-monsoon season for all weather parameters. Alternatively, seasonal usability of forecast of rainfall, cloud cover, Tmax, Tmin and wind speed were found success ranged from 87-98%, 65-75%, 51-72%, 56-67% and44-83%, while, early usability was ranged 93-96%, 63-73%, 45-70%, 56-70% and 35-87%, respectively among study locations. Moreover, among study locations, the whole year RMSE was observed in the range from 3.95-5.12 mm, 2.71-2.80 Okta, 2.83-2.85 °C, 2.39-2.51 °C and 5.79-7.47 kmph, while, the value of correlation coefficient ranged from 0.68-0.83, 0.39-0.44, 0.92-0.93, 0.95-0.96 and 0.35-0.43 in respect of rainfall, cloud cover, maximum temperature, minimum temperature and wind speed, respectively. Moreover, adopted agro-meteorological advisory services (AAS) was found valuable, in which, better yield and its attributes were observed

over non-adopted AAS for both the crops and study locations. Furthermore, an additional net return of Rs. 4055 and Rs. 1900 per acre for cotton, while, Rs. 5461 and Rs. 5045 per acre for wheat crop were obtained with the use of adopted AAS for timely and late sown conditions, respectively. On the other hand, adopted AAS showed 17 % and 21 % higher net profit for cotton and 26 % and 18 % higher net profit for wheat with timely and late sown crop, respectively.

Keywords – Medium range weather forecasts, reliability, usability analysis, root mean square error, correlation coefficient.

1. Introduction

Weather forecast related to agriculture is helpful in reducing the cost of cultivation of crops and increases the crop yield. Reliable and timely weather forecast also provides significant and useful inputs for precise impact assessment for agricultural activities. The degree of vulnerability of crops to climate variability depends mainly on the developmental stage of the crops at the time of weather aberration (Lansigan *et al.,* 2000). Weather forecast can help farmers to take intelligent decisions about selection of crops, date of crop sowing/ planting and crop preventive measures to maximize the crop yields, so that, they can get benefit from good seasons and minimize the adverse effect of climate for their crops (Cabrera *et al.,* 2009).

A timely medium range forecast provides tremendous benefits for appropriate management of aberrant weather. Farmers could thereby adjust their cropping patterns and plan agricultural operations in order to obtain maximum production even during adverse weather conditions. Inspite of national and regional level of agro advisory services (Lunagaria *et al*., 2009), district level agro advisory services is also prepared in order to provide maximum benefits of weather based AAS to the farmers. Thus, the importance of weather forecasting inclined moderately due to climate change for crop production at farmers as well as crop decision level (Cabrera *et al.,* 2009). More than 60 % farmers realized that the weather prediction and Agromet Advisory Services (AAS) to be useful for irrigation time, fertilizer time, pest and disease management and also for harvesting of crops (Khichar and Bishnoi, 2003).

Agromet advisory services based on medium range weather forecasts have been identified as a micro level management strategy for mitigating the impact of climatic variations on agricultural production and income (Devi and Rao, 2008). The farmer, generally who followed the Agromet-advisory Services (AAS), are able to reduce the input cost and increase in the net profit as compared to the non-AAS farmer. Thus, the application of AAS, based on observed and forecasted weather is a useful tool for enhancing income of crop production. The gain can be either through decreasing input cost for the farm management or through increasing production through decreasing of losses (Manjappa and Yeledalli, 2013).

The main aim of Agromet-advisory services is to preserve natural sources efficiently and contact for minimizing the weather risks. Agromet advisory services based on medium range weather forecasts have been identified as a micro level management strategy for mitigating the impact of climatic variations on agricultural production and income (Devi and Rao, 2008). In fact, short and medium-range weather forecast plays a big function in making short term adjustments in daily agricultural operations.

Cotton, except, the maximum important industrial crop, contributing approximately 70% of the total raw material to the textile industries of our country, therefore, it is also known as “backbone of textile industry”. In India, it occupied an area of 122.35 lakh ha with annual production of 377 lakh bales of 170 kg and productivity of 523.83 kg ha^{-1}during 2017. In Punjab, during 2017-18, cotton crop covered an area of 3.85 lakh ha with production of 12 lakh bales and productiveness of 529.87 kg ha^{-1} (Anonymous 2018). Moreover, India is the second biggest wheat generating nation wherein area beneath wheat becomes 30.23 million hectares with production of 93.50 million tonnes and yield of 3093 kg ha^{-1} during 2015-16 (Agricultural Statistics, 2016). In Punjab, it occupied an area of 3.50 million hectares with a production of 16.44 million tonnes and productiveness of 4704 kg ha^{-1} during 2016-17 (Anonymous, 2017).

So, keeping in view of the above facts, in the present study efforts have been made to verify the suitability of the medium range weather forecast and its economic impact on cotton-wheat cropping system as these are the major crops growing in the South-Western region of Punjab.

2. Material and methods

2.1. *Usability analysis of medium range weather forecast*

The value-added medium range weather forecast (MRWF) indicates weather forecast for 5 days in advance along with two days of outlook, received for Bathinda and Faridkot from Meteorological Centre, Chandigarh for minimum and maximum temperature (°C), rainfall (mm), cloud cover (okta) and wind speed (kmph) from

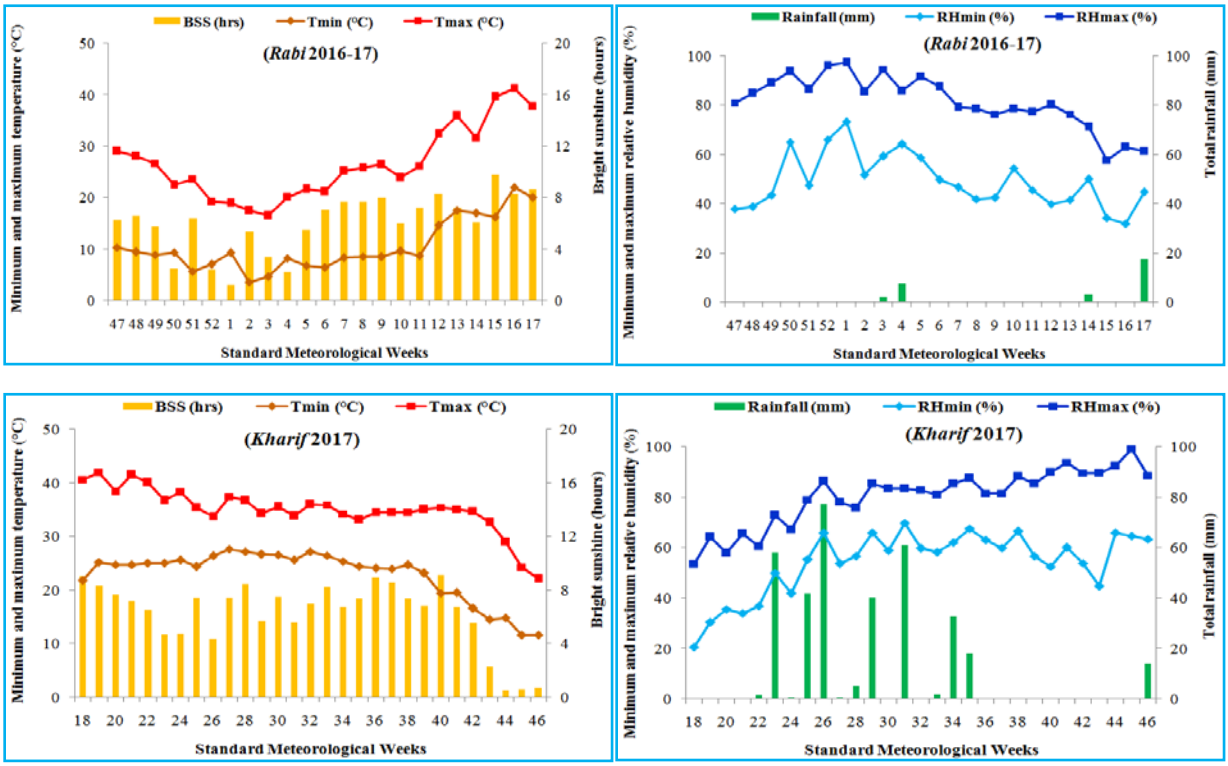


Fig. 1. Weekly weather conditions in terms of minimum and maximum temperature, bright sunshine, minimum and maximum relative humidity and rainfall for the study location of Bathinda during Rabi 2016-17 and *Kharif* 2017

TABLE 1

Critical values for error structure for usability analysis of medium range weather forecast

Usability	Rainfall (mm)		Tmax and Tmin (°C)	Cloud cover (okta)	Wind speed (Kmph)
	(≤ 10mm)	(> 10mm)			
Correct	Diff ≤ 0.2 mm	Diff ≤ 2% of obs	Diff ≤ 1°C	Diff ≤ 1 okta	Diff ≤ 3 kmph
Usable	0.2 mm < Diff ≤ 2.0 mm	2% of obs< Diff ≤ 20% of obs	1°C < Diff ≤ 2°C	1 okta< Diff ≤ 2 okta	3 kmph< Diff ≤ 6 kmph
Unusable	Diff >2.0 mm	Diff > 20% of obs	Diff > 2°C	Diff > 2 okta	Diff > 6 kmph

Diff = Absolute difference of observed and forecast weather parameter, Obs = Observed weather parameter

2013-2017. However, actual weather data was obtained from Agro-meteorological Observatory of both the respective stations during the period of 2013-2018. Seasonal analysis of the forecast verification was done for four seasons as per standard of IMD *i.e.*, pre-monsoon season (April - May), monsoon season (June - September), post-monsoon season (October - December) and winter season (January - March). In this regards, usability analysis of forecast was done in three categories *i.e.*, correct, usable and unusable based on the forecast and observed values for the weather parameters, using the critical error structure given in Table 1 (Kaur and Singh, 2019).

2.2. *Skill Score analysis of medium range weather forecast*

Based on the 2 ×2 contingency table, Ratio score and Hansen and Kuipers (H.K.) score were determined for qualitative analysis of the rainfall forecast by using the following formulae (Kaur and Singh, 2019):

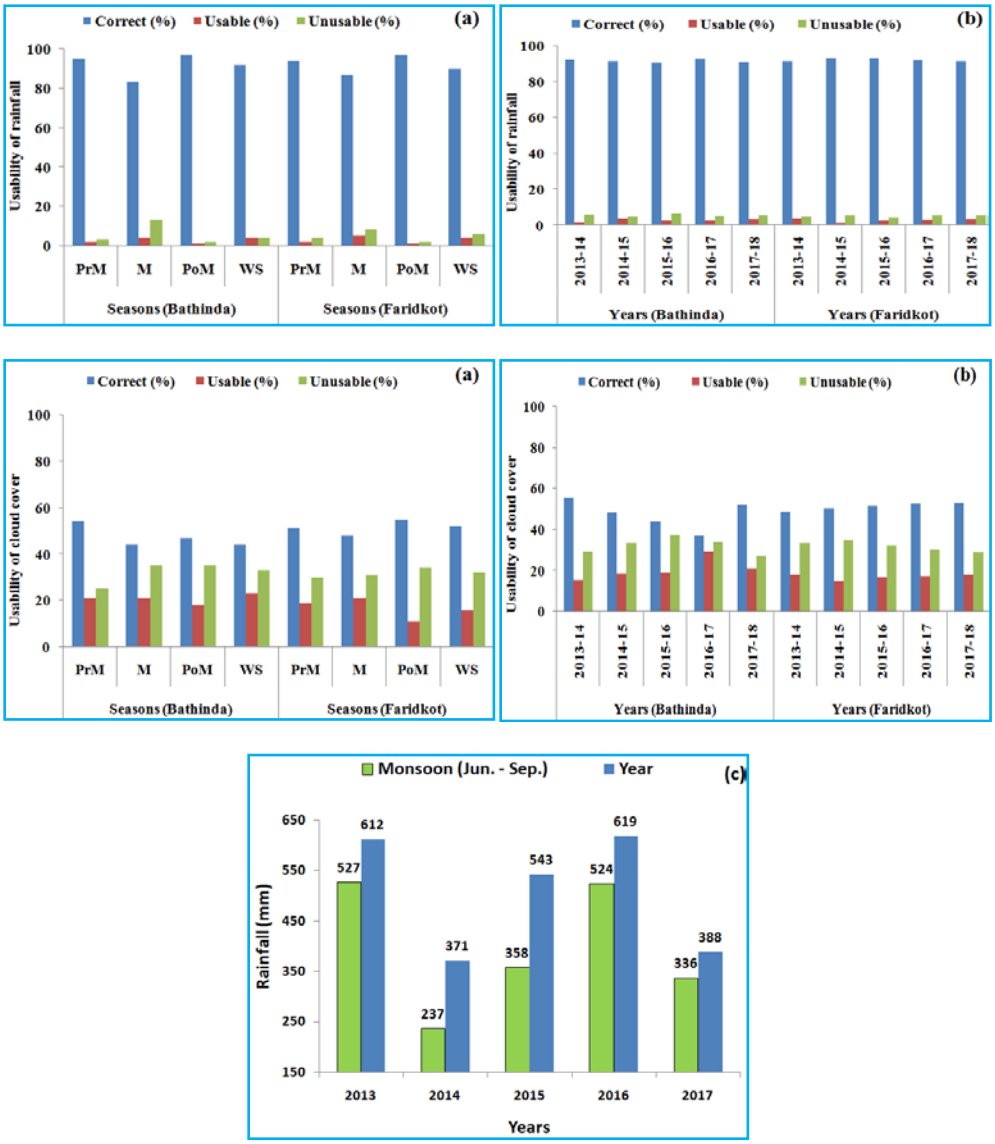
$$\text{Ratio Score} = \frac{YY + NN}{N} \times 100$$

$$\text{H.K. Score} = \frac{YYNN + YNNY}{(YY + YN)(NY + NN)}$$

TABLE 2

Root mean square error (RMSE) between observed and forecasted weather parameters for Bathinda and Faridkot

Seasons	Bathinda						Faridkot					
	2013-14	2014-15	2015-16	2016-17	2017-18	Average	2013-14	2014-15	2015-16	2016-17	2017-18	Average
Rainfall												
Pre-monsoon (Apr-May)	0.46	2.69	1.20	0.79	1.62	1.35	2.69	3.59	4.19	3.44	1.57	3.10
Monsoon (Jun-Sep)	10.15	7.17	8.47	8.72	7.66	8.43	5.42	5.33	6.52	6.41	5.21	5.78
Post-monsoon (Oct-Dec)	0.81	1.27	0.99	1.19	0.97	1.05	1.27	0.73	0.72	1.34	0.74	0.96
Winter (Jan-Mar)	3.73	3.98	2.36	1.16	1.14	2.47	3.98	7.37	3.64	1.03	1.55	3.51
Whole year (Apr-Mar)	6.24	4.64	5.04	5.12	4.54	5.12	3.56	4.54	4.41	4.06	3.17	3.95
Cloud cover												
Pre-monsoon (Apr-May)	2.03	2.52	2.33	2.27	1.59	2.15	2.52	2.36	2.37	2.96	2.52	2.55
Monsoon (Jun-Sep)	2.72	2.62	2.07	2.39	2.97	2.55	2.62	2.73	2.29	2.83	2.79	2.65
Post-monsoon (Oct-Dec)	2.88	2.94	3.57	3.05	2.96	3.08	2.95	3.17	3.65	2.95	2.62	3.07
Winter (Jan-Mar)	3.51	2.63	2.94	2.19	1.68	2.59	2.62	3.12	3.09	2.19	2.51	2.71
Whole year (Apr-Mar)	2.82	2.72	2.84	2.58	2.60	2.71	2.72	2.89	2.95	2.80	2.64	2.80
Maximum temperature												
Pre-monsoon (Apr-May)	2.92	2.75	2.94	0.79	2.97	2.47	3.23	4.05	3.02	2.76	2.71	3.15
Monsoon (Jun-Sep)	3.16	2.53	2.66	3.04	2.89	2.86	2.53	3.22	2.41	2.40	2.57	2.63
Post-monsoon (Oct-Dec)	2.66	3.77	2.97	2.41	2.67	2.90	3.80	3.42	2.89	2.22	2.62	2.99
Winter (Jan-Mar)	2.88	3.61	1.86	1.96	1.92	2.45	3.61	3.08	2.25	2.16	1.99	2.62
Whole year (Apr-Mar)	2.91	3.21	2.70	2.64	2.70	2.83	3.29	3.42	2.66	2.37	2.53	2.85
Minimum temperature												
Pre-monsoon (Apr-May)	3.29	2.85	2.61	3.05	2.76	2.91	2.85	2.94	2.66	3.24	2.28	2.79
Monsoon (Jun-Sep)	1.98	2.35	2.12	1.95	2.00	2.08	2.35	2.83	2.52	2.03	2.56	2.46
Post-monsoon (Oct-Dec)	2.25	2.31	2.84	1.91	1.80	2.22	2.29	2.37	2.59	2.09	1.86	2.24
Winter (Jan-Mar)	2.57	3.61	2.39	2.10	2.40	2.61	3.60	3.48	2.54	2.02	2.09	2.75
Whole year (Apr-Mar)	2.43	2.67	2.50	2.18	2.15	2.39	2.66	2.82	2.57	2.29	2.22	2.51
Wind speed												
Pre-monsoon (Apr-May)	3.72	3.84	5.33	5.40	5.43	4.74	3.84	6.97	8.23	7.79	5.25	6.42
Monsoon (Jun-Sep)	3.90	4.36	8.68	6.86	6.53	6.07	4.36	9.03	12.36	10.12	7.91	8.76
Post-monsoon (Oct-Dec)	4.78	5.62	5.85	5.10	6.04	5.48	5.58	6.25	7.38	7.06	5.44	6.34
Winter (Jan-Mar)	5.01	7.80	7.02	5.59	7.09	6.50	7.69	9.21	8.6	5.94	5.00	7.29
Whole year (Apr-Mar)	4.38	5.41	7.02	5.87	6.29	5.79	5.37	7.89	9.62	8.18	6.29	7.47



Figs. 2(a-c). Season-wise (a) and year-wise (b) usability of the medium range rainfall, cloud cover forecast for Bathinda and Faridkot and monsoon period rainfall (c) during 2013-14 to 2017-18

where,

YY = Number of days when rain was forecasted as well as observed

YN = Number of days when rain was forecasted but not observed

NY = Number of days when rain was not forecasted but observed

NN = Number of days when rain was neither forecasted nor observed

2.3. *Experimental site and weather conditions*

In order to study the economic impact of medium range weather forecast, the field experiment was conducted at Punjab Agricultural University (PAU), Regional Research Station, Bathinda, (30° 09"36' N, 74° 55"28' E, 211m above mean sea level) during the *Rabi* season 2016-17 for wheat and *Kharif* 2017 for cotton crop. Study region falls under South-Western part of the state in 5thAgro Climatic region of Punjab and its weather is classified as semi-arid. The normal annual rainfall of the region is 436 mm. Frosty night associated with chilled winds are not unusual while night temperature touches

0°C during December-January and dust storms are common in May-June when the mercury touches over 47°C.

Moreover, in respect of weekly weather conditions during *Rabi* 2016-17, a total of 30.1 mm rainfall was received at Bathinda, which was occurred mainly in 3rd, 4th, 14th and 17th standard meteorological weeks (SMW) during 2017. However, the weekly mean bright sunshine was ranged from 1.2 hours (1st SMW) to 9.8 hours (15th SMW) during the *Rabi* 2016-17. Moreover, weekly mean minimum as well as maximum relative humidity was ranged from 31.9 - 65.0 % and 57.7 - 97.3 %, respectively. Furthermore, during the period of *Rabi* 2016-17, the weekly mean minimum as well as maximum temperature was observed between 3.5 - 22.0°C and 16.5 - 41.2°C, respectively (Fig. 1).

Similarly, based on weekly weather data during *Kharif* 2017, a total of 352.2 mm rainfall was received at Bathinda from 20th to 35th SMW. While, weekly mean bright sunshine was ranged from 0.0 hours (44th SMW) to 9.1 hours (18th SMW) during the *Kharif* 2017. Moreover, weekly mean minimum as well as maximum relative humidity was ranged from 20.6 - 69.7 % and 53.3 - 99.1 %, respectively. During the period of *Kharif* 2017, the weekly mean minimum as well as maximum temperature was observed between 11.6 - 27.7°C and 22.1 - 42.0°C, respectively (Fig. 1).

2.4. *Cost of input and output based on adopted vs. non-adopted Agromet Advisory Services for cotton-wheat cropping system*

Economics of cotton and wheat crops was calculated by using prevailing prices for inputs and produce of the crop like seed, manure and fertilizers, labour used from land preparation to harvesting of the crop and plant protection as pesticides, fungicides and herbicides applications etc. under adopted and non-adopted Agromet Advisory Services. Moreover, the quantity of yield produced for wheat and cotton was treated as the total output. Gross return was calculated by multiplying the grain yield of wheat and seed cotton yield of cotton crop with their respective selling prices.

2.5. *Statistical analysis*

The root mean square error (RMSE) of weather parameters was worked out to find out absolute error between observed and forecasted weather data of the station. The root mean square error (RMSE) was computed using the expression detailed by Hyndman and Koehler (2006). Moreover, based on the observed data and IMD forecast of Bathinda and Faridkot, correlation coefficients have been calculated and also checked their significance level at 5% and 1% for the different seasons *i.e.,* pre-monsoon (61 days), monsoon (122 days), post-monsoon (92 days) winter season (90 days) and whole year (365 days).

3. Results and discussion

3.1. *Usability analysis of the medium range weather forecast at Bathinda and Faridkot*

The correctness, usability, and un-usability of the five days medium range weather forecast in terms of rainfall, cloud cover during 2013-14 to 2017-18 at Bathinda and Faridkot are depicted in Fig. 2(a) (season-wise) and Fig. 2(b) (year-wise), respectively. While, usability analysis of wind speed, minimum temperature and maximum temperature are depicted in Fig. 3(a) (season-wise) and Fig. 3(b) (year-wise), respectively. The root mean square error (RMSE) and correlation coefficient between observed and forecasted weather parameters for the study locations of Bathinda and Faridkot during 2013-14 to 2017-18 are given in Tables 2 and 3, respectively.

3.1.1. *Rainfall*

The results revealed that, at Bathinda, among different seasons, rainfall accuracy ranged in between 95-100, 78- 96, 96-99 and 83-96 per cent having average rainfall forecast successfulness by 95, 83, 97, 92 and 92 per cent from 2013-14 to 2017-18 for pre-monsoon, monsoon, post-monsoon and winter season, respectively. However, in respect of whole year rainfall forecast, the accuracy was found between 90 to 93 per cent. The highest correct and usable cases coincided with post monsoon season (low rainfall season), *i.e.,* 93.9 percent when verified for 5 days average forecast. The rainfall forecast during low rainfall seasons was found highly reliable (70 to 90 %). Chauhan *et al*.,(2008) and Rana *et al*.,(2013) also revealed that the performance of rainfall forecast was good in pre-monsoon, post-monsoon and winter season. Lunagaria *et al*., (2009) also recorded lowest percent of rainfall usability during the monsoon season for Gujarat. Similarly, at Faridkot, correctness of the rainfall forecast ranged between 92-98, 84-93, 96-99 and 83-94 per cent, while, average rainfall forecast was found accurate by 97, 83, 98 and 92 per cent for pre-monsoon, monsoon season, post-monsoon and winter season, respectively [Figs. 2(a&b)].

In terms of statistical analysis, the average value of RMSE for rainfall among different seasons was found to be lowest during post-monsoon season (BTI: 1.05, FDK: 0.96) which represents a very low error between the forecasted and observed values, while, highest RMSE

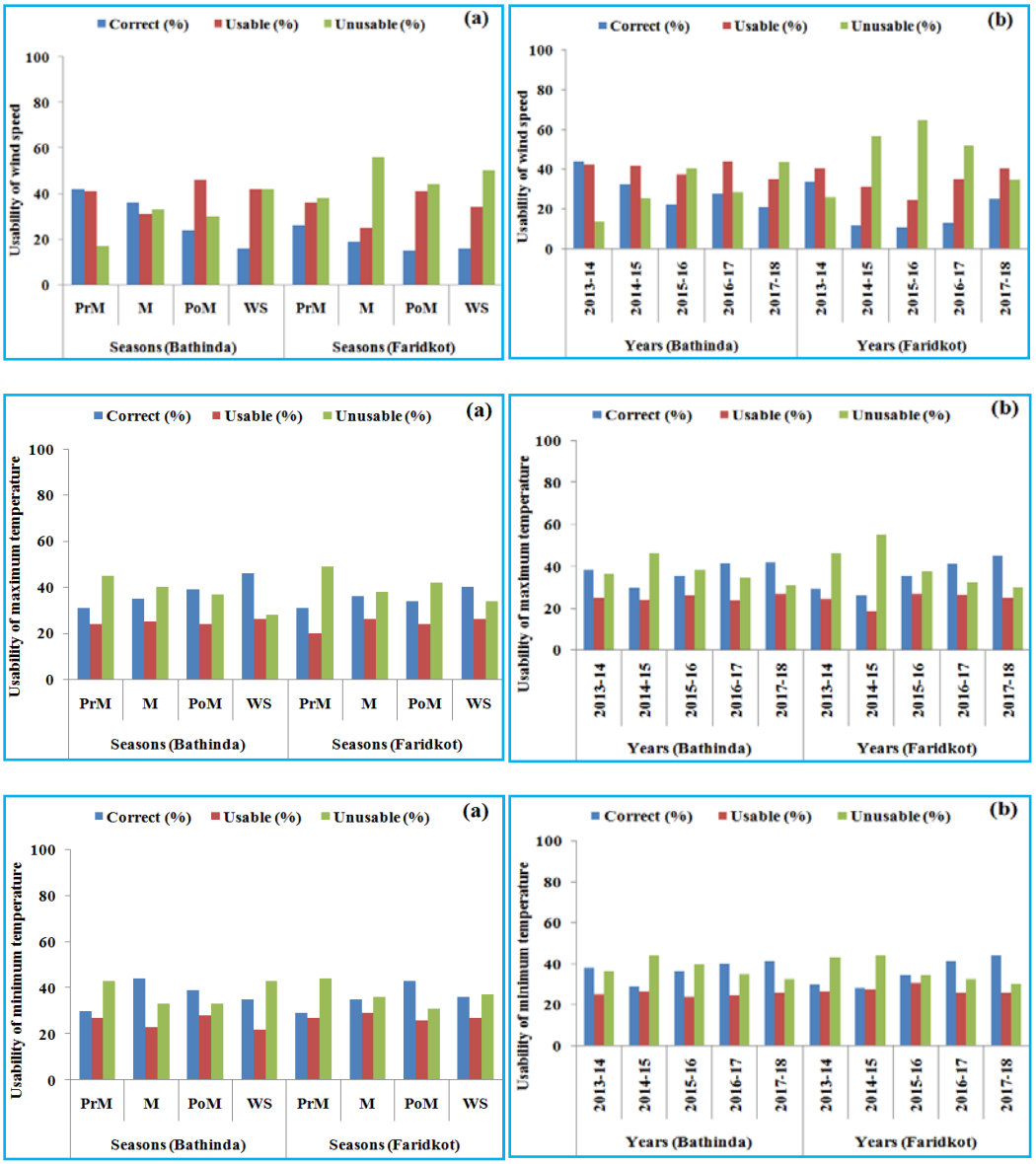
TABLE 3

Correlation coefficient between observed and forecasted weather parameters for Bathinda and Faridkot

Seasons	Bathinda						Faridkot					
	2013-14	2014-15	2015-16	2016-17	2017-18	Average	2013-14	2014-15	2015-16	2016-17	2017-18	Average
Rainfall												
Pre-monsoon (Apr-May)	0.96	0.82	0.95	0.99	0.87	0.92	0.82	0.76	0.04*	0.92	0.85	0.68
Monsoon (Jun-Sep)	0.65	0.65	0.49	0.83	0.61	0.65	0.74	0.94	0.89	0.71	0.89	0.83
Post-monsoon (Oct-Dec)	0.96	0.34	0.54	0.92	0.75	0.70	0.34	0.23**	0.01*	0.58	0.63	0.36
Winter (Jan-Mar)	0.08*	0.84	0.67	0.74	0.04*	0.47	0.84	0.84	0.77	0.94	0.88	0.85
Whole year (Apr-Mar)	0.66	0.69	0.57	0.84	0.64	0.68	0.79	0.90	0.86	0.72	0.88	0.83
Cloud cover												
Pre-monsoon (Apr-May)	0.59	0.35	0.46	0.44	0.56	0.48	0.35	0.39	0.29**	0.30**	0.41	0.35
Monsoon (Jun-Sep)	0.54	0.49	0.74	0.47	0.26	0.5	0.49	0.4	0.67	0.50	0.43	0.50
Post-monsoon (Oct-Dec)	0.31	0.47	0.17*	0.27	0.33	0.31	0.46	0.37	0.21*	0.46	0.59	0.42
Winter (Jan-Mar)	0.19*	0.54	0.12*	0.55	0.38	0.36	0.54	0.35	0.36	0.60	0.41	0.45
Whole year (Apr-Mar)	0.46	0.46	0.44	0.38	0.23	0.39	0.46	0.37	0.39	0.49	0.50	0.44
Maximum temperature												
Pre-monsoon (Apr-May)	0.82	0.82	0.84	0.73	0.69	0.78	0.77	0.81	0.84	0.69	0.76	0.77
Monsoon (Jun-Sep)	0.66	0.80	0.64	0.60	0.54	0.65	0.80	0.75	0.64	0.68	0.61	0.70
Post-monsoon (Oct-Dec)	0.92	0.90	0.89	0.93	0.91	0.91	0.90	0.89	0.90	0.94	0.92	0.91
Winter (Jan-Mar)	0.78	0.67	0.85	0.90	0.90	0.82	0.66	0.71	0.79	0.89	0.90	0.79
Whole year (Apr-Mar)	0.94	0.93	0.93	0.94	0.93	0.93	0.93	0.92	0.93	0.95	0.94	0.93
Minimum temperature												
Pre-monsoon (Apr-May)	0.80	0.81	0.73	0.71	0.79	0.77	0.81	0.75	0.67	0.65	0.82	0.74
Monsoon (Jun-Sep)	0.62	0.49	0.42	0.46	0.38	0.47	0.49	0.43	0.33	0.44	0.46	0.43
Post-monsoon (Oct-Dec)	0.94	0.92	0.91	0.95	0.96	0.94	0.92	0.91	0.92	0.93	0.94	0.92
Winter (Jan-Mar)	0.76	0.52	0.82	0.89	0.85	0.77	0.52	0.52	0.79	0.88	0.85	0.71
Whole year (Apr-Mar)	0.96	0.95	0.95	0.97	0.97	0.96	0.95	0.94	0.93	0.96	0.97	0.95
Wind speed												
Pre-monsoon (Apr-May)	0.20*	0.55	0.45	0.48	0.54	0.43	0.55	-0.09*	-0.06*	0.51	0.57	0.30**
Monsoon (Jun-Sep)	0.40	0.52	0.26	0.46	0.25	0.38	0.52	0.10**	0.24**	0.17*	0.46	0.30
Post-monsoon (Oct-Dec)	0.25	0.35	0.28	0.40	0.26	0.36	0.34	-0.09*	0.29	0.29	0.29	0.22**
Winter (Jan-Mar)	0.27**	0.43	0.43	0.34	0.35	0.31	0.42	0.31**	-0.18*	0.12*	0.15*	0.16*
Whole year (Apr-Mar)	0.33	0.43	0.38	0.57	0.44	0.44	0.43	0.13	0.29	0.38	0.54	0.35

All significant at 0.05 Probability level except *value

was observed with monsoon season (BTI : 8.43, FDK : 5.78). Moreover, during whole year, RMSE of rainfall was observed as 5.12 and 3.95 for Bathinda and Faridkot, respectively (Table 2). Similarly, in respect of correlation coefficient, among seasons at Bathinda, lowest value was found during winter season with 0.47 but highest during pre-monsoon season (0.92), while, at Faridkot, lowest during post-monsoon with 0.36 and highest in monsoon season (0.83). Moreover, as whole year, correlation coefficient of rainfall was observed as 0.68 and 0.83 for Bathinda and Faridkot, respectively (Table 3).



Figs. 3(a&b). Season-wise (a) and year-wise (b) usability of the medium range wind speed, maximum temperature and minimum temperature forecast for Bathinda and Faridkot during 2013-14 to 2017-18

3.1.2. *Cloud cover*

The results revealed that the average correct cloud cover forecast was observed 54, 44, 47, 44 and 47 per cent successful at Bathinda and 70, 48, 66, 52 and 51 per cent successful at Faridkot for pre-monsoon, monsoon, post-monsoon, winter season and whole year, respectively. Moreover, among different seasons, during pre-monsoon, monsoon, post-monsoon and winter seasons, the success of cloud cover forecast ranged between 65-86, 51-78, 32-61 and 28-72 per cent at Bathinda 43-61, 42-61, 39-61 and 43-61 per cent at Faridkot, respectively. Rana *et al.*,(2013) also analysed winter season cloud cover forecast for 5 days (46.2%) as average forecast. Lower values of forecasted cloud cover were recorded in winter and hot seasons and higher values of forecasted cloud cover were recorded in SW monsoon and post-monsoon seasons [Figs. 2(a&b)].

Statistically, the average RMSE was found in ranged between 2.15 - 3.08 and 2.55 - 3.07 okta for Bathinda and Faridkot, respectively having lowest value during pre-monsoon season and highest in pre-monsoon season (Table 2). While, the value of correlation coefficient ranged between 0.31-0.50 and 0.35-0.50 for Bathinda and Faridkot, respectively. During whole year, correlation

coefficient indicated the positive relation (BTI: 0.39, FDK:0.44), while, overall results indicate that the forecast is moderately good (Table 3).

3.1.3. *Maximum temperature*

The success of maximum temperature forecast as mean from 2013-14 to 2017-18 was found successful by 31, 35, 39, 46 and 37 and Bathinda and 51, 36, 58, 40 and 60 per cent at Faridkot for pre-monsoon, monsoon, post-monsoon, winter seasons and whole year, respectively. On the other hand, among seasons, the success of maximum temperature forecast ranged between 27-64 and 15-57 per cent at Bathinda and Faridkot, respectively. However, as the whole year correct maximum temperature forecast ranged between 29-41 and 27-44 per cent at Bathinda and Fardkot, respectively [Figs. 3(a&b)]. Mummigatti *et al.*, (2013) revealed that usability for maximum temperature was highest during post-monsoon (82.0%) and winter season (81.0%). Rana *et al*., (2013) also revealed that, the high degree of association between forecasted and observed values of temperature was observed in all the seasons.

Moreover, in respect of maximum temperature, the average RMSE was found in between 2.45 to 2.90 and 2.62 to 3.15°C, while, as whole year it was 2.83 and 2.85°C for Bathinda and Faridkot, respectively. Among seasons, lowest RMSE was observed during winter season and highest with post-monsoon season (Table 2). Similarly, the average correlation coefficient was observed between 0.65 to 0.91 and 0.70 to 0.91, while, as whole year forecast it was 0.92 and 0.93 for Bathinda and Faridkot, respectively. Alternatively, among the forecast parameters, the highest value of correlation coefficient was found with minimum and maximum forecast having also least value of RMSE, indicated better usability of the forecast (Table 3).

3.1.4. *Minimum temperature*

The minimum temperature average forecast was observed 30, 44, 39, 35 and 39 per cent successful at Bathinda, while, 30, 44, 39, 35 and 39 per cent successful at Faridkot during pre-monsoon, monsoon, post-monsoon, winter seasons and whole year, respectively. Moreover, among different seasons, the success minimum temperature forecast ranged between 25-73 and 17-59 per-cent successful at Bathinda and Faridkot, respectively. However, during whole year correct minimum temperature forecast ranged between 32 to 43 per cent at both the places [Figs. 3(a&b)]. Such results for minimum temperature was also obtained by the study conducted by Das and Desai (2018) and revealed that the average performance of minimum temperature forecast was good in post monsoon seasons (69%).

In view of statistical analysis, the higher value of mean RMSE was found during pre-monsoon season which indicated poor usability of forecast in the season. Moreover, the average RMSE was found between 2.08 to 2.91 and 2.24 to 2.79°C, while, whole year RMSE was found 2.39 and 2.51 °C for Bathinda and Faridkot, respectively (Table 2). Alternatively, the value of average correlation coefficient was ranged 0.47 to 0.94 and 0.43 to 0.92 for Bathinda and Faridkot, respectively. While, as whole year forecast, highly significant and positive correlation was found at both the study locations (BTI : 0.96, FDK : 0.95) indicated quality forecast (Table 3).

3.1.5. *Wind speed*

The results revealed that, among the study locations, average wind speed forecast was observed 42-63, 36-19, 24-56 and 16-17 per cent successful for pre-monsoon, monsoon, post-monsoon and winter seasons, respectively. On the other hand, pre and post monsoon season indicated higher accuracy of wind speed forecast over actual at both the places. However, as whole year correct wind speed forecast, the success was ranged between 21 to 45 per cent [Figs. 3(a&b)]. Similar results of usability analysis for wind speed were also found through the study by Das and Desai (2018) and revealed that the average performance of wind speed forecast was excellent in pre monsoon and post monsoon (94%).

Statistically, as whole year forecast, the value of RMSE (BTI : 5.79, FDK : 7.47) appears to be moderately high and showed higher error with a wide difference between the predicted and observed values. Moreover, among different seasons, the average RMSE of wind speed was found highest during monsoon season followed by other season at both the study locations, which indicated poor quality of forecast in the respective season (Table 2). On the other hand, among season and year, the lowest value of correlation coefficient was observed with the wind speed forecast than other forecast parameters. Moreover, average correlation coefficient value was found highest during pre-monsoon (BTI : 0.43, FDK : 0.30) and lowest during winter season (BTI : 0.31, FDK : 0.16) (Table 3).

3.2. *Skill score analysis of medium range rainfall forecast for Bathinda and Faridkot*

The skill score analysis of medium range weather forecast based on H.K. score and Ratio score during 2013-14 to 2017-18 is given in Table 4. The results revealed that the average HK score from 2013-14 to 2017-18 were accounted as 0.61, 0.42, 0.66 and 0.54 while, ratio score was achieved to 94.10, 74.10, 97.56 and 89.54 per cent for

TABLE 4

Skill score analysis (H.K and Ratio Score) of medium range weather forecast for Bathinda and Faridkot

Seasons	Bathinda		Faridkot	
	H.K. Score	Ratio Score (%)	H.K. Score	Ratio Score (%)
2013-14				
Pre-monsoon (Apr-May)	0.75	98.36	0.68	93.44
Monsoon (Jun-Sep)	0.51	83.61	0.28	80.33
Post-monsoon (Oct-Dec)	0.99	99.19	0.49	96.75
Winter (Jan-Mar)	0.17	77.97	0.76	91.53
Whole year (Apr-Mar)	0.53	90.41	0.55	90.14
2014-15				
Pre-monsoon (Apr-May)	0.68	93.44	0.52	90.16
Monsoon (Jun-Sep)	0.26	80.33	0.29	86.07
Post-monsoon (Oct-Dec)	0.49	96.75	0.33	96.75
Winter (Jan-Mar)	0.76	91.53	0.33	81.36
Whole year (Apr-Mar)	0.51	89.86	0.36	89.59
2015-16				
Pre-monsoon (Apr-May)	0.45	91.80	0.23	93.44
Monsoon (Jun-Sep)	0.48	75.41	0.38	76.23
Post-monsoon (Oct-Dec)	0.31	95.93	0.22	95.12
Winter (Jan-Mar)	0.31	86.67	0.46	88.33
Whole year (Apr-Mar)	0.51	86.89	0.42	87.70
2016-17				
Pre-monsoon (Apr-May)	0.75	98.36	0.80	98.36
Monsoon (Jun-Sep)	0.56	74.59	0.60	78.69
Post-monsoon (Oct-Dec)	0.74	98.37	0.80	99.19
Winter (Jan-Mar)	0.98	98.31	0.90	98.31
Whole year (Apr-Mar)	0.74	90.41	0.77	92.05
2017-18				
Pre-monsoon (Apr-May)	0.43	88.52	0.16	86.89
Monsoon (Jun-Sep)	0.31	56.56	0.56	66.39
Post-monsoon (Oct-Dec)	0.78	97.56	0.74	98.37
Winter (Jan-Mar)	0.46	93.22	0.96	96.61
Whole year (Apr-Mar)	0.53	81.64	0.70	85.48
Average				
Pre-monsoon (Apr-May)	0.61	94.10	0.48	92.46
Monsoon (Jun-Sep)	0.42	74.10	0.42	77.54
Post-monsoon (Oct-Dec)	0.66	97.56	0.52	97.24
Winter (Jan-Mar)	0.54	89.54	0.68	91.23
Whole year (Apr-Mar)	0.56	87.84	0.56	88.99

Bathinda, while, in respect of Faridkot average HK score were observed as 0.48, 0.42, 0.52 and 0.68, ratio score was accounted as 92.46, 77.54, 97.24 and 91.23 per cent for pre-monsoon, monsoon, post-monsoon and winter season, respectively.

Moreover, among the years, the maximum HK Score was found to be 0.74 during 2016-17 and ratio score was 90.41 per cent during 2013-14 and 2016-17, while, among different seasons, post-monsoon season showed most skilful forecast in terms of higher HK score and Ratio score at Bathinda. Similarly, at Faridkot the maximum HK Score was found to be 0.77 and ratio score (92.05%) during 2016-17. Among different seasons, winter season showed most skilful success in HK score and post-monsoon season in respect of Ratio score at Faridfot (Table 4). Das and Desai (2018) also revealed that the HK score in post monsoon and winter seasons in this region found accuracy of rainfall forecasts nearly 100 percent correct in these seasons. Chauhan *et al*. (2008) also showed that the accuracy of rainfall forecast became useful in pre-monsoon and winter seasons having good HK Score.

During the monsoon season (June - September) of the study period, highest rainfall was received in the year 2013 (527 mm) followed by 2016 (524 mm). While, minimum rainfall during monsoon period was obtained in 2014 (237 mm) followed by 2017 (336 mm) [Fig. 2(c)]. Similarly, total year-wise rainfall was highest in 2016 (619 mm) than 2013 (612 mm) and received minimum in 2014 (371 mm) than 2017 (388) [Fig. 2(c)].

3.3. *Economic impact assessment of Agromet advisory services on wheat and cotton crop production*

3.3.1. *Comparative analysis of cost of cultivation on wheat crop production*

The comparative analysis of cost of cultivation of wheat crop on the basis of adopted Agromet Advisory Services (AAS) (A1) and non-adopted AAS (A2) for two dates of sowing, *i.e*., November 29 and December 13, 2016 is presented in Table 5. The total variable cost of cultivation from field preparation to harvesting was Rs.15242 and Rs.16247 per acre for adopted-AAS (A1) and non-adopted AAS (A2), respectively for crop sown on November 29, 2016, while, it was Rs.15242 and Rs.15617 per acre for adopted AAS (A1) and non-adopted AAS (A2) respectively for crop sown on 13Dec, 2016.

With the timely sown crop (November 29), the crop production of main product (grain yield) was recorded 20.0 quintal per acre for adopted AAS (A1) and 18.0

TABLE 5

Comparative analysis of cost of cultivation on wheat crop production

Treatments	November 29, 2016				December 13, 2016			
	A1 (AAS)		A2 (Non-AAS)		A1 (AAS)		A2 (Non-AAS)	
	Qty.	Rs.	Qty.	Rs.	Qty.	Rs.	Qty.	Rs.
1. Seed (kg)	40	1200	40	1200	40	1200	40	1200
2. Manures & fertilizers(kg)								
(i) Urea	90	490	90	490	90	490	90	490
(ii) DAP	55	1238	55	1238	55	1238	55	1238
(iii) Muriate of Potash	20	296	20	296	20	296	20	296
Sub total	-	2024	-	2024	-	2024	-	2024
3. Pesticides, weedicides & fungicides								
(i) Stomp 30 EC (ml)	1000	500	1000	500	1000	500	1000	500
(ii)2,4-D Sodium Salt (g)	250	88	250	88	250	88	250	88
(iii) Rogor (ml)	150	50	150	50	150	50	150	50
(iv) Tilt 25 EC (ml)	200	210	200	210	200	210	200	210
Sub total	-	848	-	848	-	848	-	848
4. No. of irrigations	4	240	5	300	4	240	5	300
5. Human labour @Rs. 315per day	14	4410	17	5355	14	4410	15	4725
6. Tractor hours (Rs.360/hr)	7	2520	7	2520	7	2520	7	2520
7. Harvesting and threshing charges	-	4000	-	4000	-	4000	-	4000
Total variable costs	-	15242	-	16247	-	15242	-	15617
Gross returns of main product(q)	20	30500	18	27450	17	25925	16	24400
Net profit (Rs.)	**-**	**15258**	**-**	**11203**	**-**	**10683**	**-**	**8783**

quintal per acre for non-adopted AAS (A2). Thus, the gross return was Rs.30500 and Rs.27450 for adopted and non-adopted AAS, respectively. While, with the crop sown on December 13 (late sown), production of main product was 17.0 and 16.0 quintal per acre for adopted and non-adopted AAS, respectively. Thus, the gross return of main product of adopted-AAS (A1) was Rs.25925 and Rs.24400 for adopted and non-adopted AAS, respectively.

The net profit in terms of Rupees per acre was found higher in adopted AAS (A1) for both date of sowing. In this context, net profit was Rs.15258 per acre with crop sown on November 29 under adopted-AAS (A1) as compared to non-adopted AAS (A2) which was Rs.11203 per acre. While, with the crop sown on December13, net profit was recorded Rs.10683 and Rs. 8783 per acre for adopted AAS (A1) and non-adopted AAS (A2), respectively. Thus, there was difference of Rs.4055 and Rs.1900 per acre between adopted (A1) and non-adopted (A2) AAS for crop sown on November 29 and December 13, respectively.

3.3.2. *Comparative analysis of cost of cultivation on cotton crop production*

The comparative analysis of cost of cultivation of cotton crop during kharif season on the basis of adopted AAS and non-adopted AAS for two dates of sowing, *i.e*., May 04 and May 27, 2017 is presented in Table 6. The total variable cost of cultivation was Rs.21142 and Rs.25813 per acre for adopted AAS and non-adopted AAS, respectively for crop sown on May 04, 2017. While,

TABLE 6

Comparative analysis of cost of cultivation on cotton crop production

Treatments	May 04, 2017				May 27, 2017			
	A1 (AAS)		A2 (Non-AAS)		A1 (AAS)		A2 (Non-AAS)	
	Qty.	Rs.	Qty.	Rs.	Qty.	Rs.	Qty.	Rs.
1. Seed (kg)	0.9	1600	0.9	1600	0.9	1600	0.9	1600
2. Manures & fertilizers (kg)								
(i) Urea	120	684	120	684	120	684	120	684
(ii) DAP	27	548	27	548	27	548	27	548
Sub total	-	1232	-	1232	-	1232	-	1232
3. Pesticides, weedicides & fungicides								
(i) Stomp 30 EC (ml)	1000	500	1000	500	1000	500	1000	500
(ii) Nimbecidine(ml)	1000	450	1000	450	1000	450	1000	450
(iii) Ulala (g)	80	650	80	650	80	650	80	650
(iv) Blitox (g)	500	275	500	275	500	275	500	275
(v) 4 sprays (2% $KMNO_3$)	6	660	6	660	6	660	6	660
Sub total	-	2535	-	2535	-	2535	-	2535
4. No. of irrigations	2	130	4	260	1	65	3	195
5. Human labour (@Rs. 315per day)	41	12915	50	15750	38	11970	47	14805
6. Tractor hours	7	2730	7	2730	7	2730	7	2730
Total variable costs	-	21142	-	24107	-	20132	-	23097
Gross returns of main product (q/acre)	12.6	52416	12	49920	10.5	43680	10	41600
Net profit (Rs.)	**-**	**31274**	**-**	**25813**	**-**	**23548**	**-**	**18503**

it was Rs.23548 and Rs.18503 per acre for adopted AAS and non-adopted AAS, respectively for crop sown on May 27, 2017.

Under crop sown on May 04, production of main product (seed cotton yield) was 12.6 quintal per acre for adopted AAS (gross return Rs. 52416) and 12 quintal per acre for non-adopted AAS (gross return Rs.49920). Whereas, for crop sowing on May 27, production of main product was 10.5 quintal per acre for adopted AAS (gross return Rs.43680) and 10 quintal per acre for non-adopted AAS (gross return Rs.41600).

The net profit in terms of Rupees per acre was higher in adopted-AAS for both date of sowing. Net profit was Rs.31274 per acre with crop sown on May 04 for adopted-AAS as compared to non-adopted AAS which was Rs.25813 per acre. While, for crop sowing on May 27, net profit was Rs.23548 per acre for adopted AAS and Rs.18503 for non-adopted AAS. Thus, there was difference of Rs.5461 and Rs.5045 per acre between adopted and non-adopted AAS for crop sown on May 04 and May 27, respectively.

The findings from the Tables 5 and 6 clearly demonstrate that the input investment is lower and average production of adopted AAS was comparatively higher than the non-adopted AAS. Hence, we can say that agro-advisory services showed positive results in terms of yield, production and net income. On the other side, the reduced cost of cultivation per acre in case of adopted-AAS shows the application of agricultural inputs judiciously used and efficiently as per weather forecast support and including the advisories in operational farm management. Rana *et al*., (2013) indicated profit of AAS on farmer's field (2.1 to 5.4 per cent) and college farm

(8.9 to 14.7 per cent). Similarly, Rao and Manikandan (2008) also obtained 7.3 and 19.2% and 6.3 to 9 % higher yield in *Rabi* and *Kharif* paddy with the adopted AAS.

3.4. *Some crop cultural operations recommended during rabi 2016-17 and kharif 2017 through agromet advisories services in view of forecasted weather events*

Forecasted weather events	Crop/cultural operations recommended in advisory	Economic gain/loss
***Rabi* 2016-17**		
Weather is likely to be dry during next 48 hrs and light to moderate rain/ thundershowers likely at a few places thereafter. Warning: Ground frost likely at few places during next two nights. (14.01.17 to 18.01.17)	Due to light to moderate rain/thundershowers forecast, farmers were advised to skip the irrigation to the crops during the period	Very light rainfall received during the period which helped to maintained the moisture
Light to moderate rain/thundershowers likely at a few places during next 24 hours and at most places thereafter. Warning: Heavy rain very likely at isolated places on 25th and 26th. Thundersquall/ hailstorm with wind speed exceeding 45 kmph likely at isolated places on 25th and 26th. (25.01.17 to 29.01.17)	As per the weather warning of heavy rain on 25th and 26th with thunder squall/hailstorm, farmers are advised neither to irrigate nor spray any chemical to the crops. Due to warning of wind speed exceeding 45 km/hr likely at isolated places during 25th and 26th January, 2017 farmers are advised to keep the harvest material at safe place	Light rainfall received again during the period which saved the irrigation
Rain / Thundershower likely to occur at isolated places on 03rd & 05th. Weather will be dry during the remaining period *Warning* : Thunder-storm / Dust storm likely to occur at isolated places on 03rd&05th. (04.04.17 to 08.04.17)	As per Rain / Thundershower forecast along with Thunderstorm / Dust storm at isolated places on 03rd& 05thApril, farmers are advised to neither to irrigate nor spray any chemical to the crops and keep the harvested materials at safe places	Light rainfall received during the period and Thunder-storm /Dust storm activity occurred.
Light rain / thundershowers likely at isolated places during the period. *Warning*: Severe heat wave conditions likely at a few places during next 24 hours; heat wave at a few places during subsequent 24 hours. Thunderstorm accompanied with squall during next 48 hours. (26.04.17 to 30.04.17)	Due to rain/thundershowers forecast, farmers were advised to skip the irrigation to the crops	Light rainfall received during the period which saved the irrigation
***Kharif* 2017**		
Light to moderate rain/thundershowers likely in next 48 hours. *Warning*: Thunderstorm accompanied with squall during next 24 hours. Heavy rain likely at isolated places on 28thand 29th. (28.06.17 to 02.07.17)	Farmers were advised for not to provide irrigation to timely sown cotton, which need to be irrigated. Also, not to spray any chemical to the crop during the period	During the period moderate to heavy rainfall received which helped for rice transplanting and saved irrigation to cotton crop
Light to moderate rain/thundershowers likely at a few places during the period. (26.07.17 to 30.07.17)	As per the Light to moderate rain/thundershowers forecast during 3-4 days, farmers were advised to neither irrigate the crop nor spray any chemical to crop. Also drain the excess water from the crop field, if needed	Rainfall received during the period and farmers got benefitted for saving the irrigation of cotton and rain during the period also helped to transplant rice crop
Moderate to heavy rainfall forecast	Farmers were advised not to	Rainfall received

mostly during second fortnight of August, 2017	irrigate the field and also drain out excess water from field in case of moderate to heavy rain	during the period and saved irrigations

4. Conclusion

Among the years and seasons, maximum accuracy was found with rainfall forecast, while, least with wind speed, moreover, rainfall, cloud cover and wind speed forecast accuracy were found higher during pre-monsoon than other seasons. The overall seasonal success of the medium range weather forecast in terms of rainfall, cloud cover, maximum and minimum temperature and wind speed was ranged from 87-98%, 65-75%, 51-72%, 56-67% 44-83%, while, early usability was ranged 93-96%, 63-73%, 45-70%, 56-70% and 35-87%, respectively among study locations. Among sowing time and genotypes, adopted AAS was found beneficial, in which, better yield attributes were recorded than non-adopted AAS for both the crops. Alternatively, adopted AAS showed 17% and 21% higher net profit for cotton and 26% and 18% higher net profit for wheat with timely and late sown crop, respectively.

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