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Validation of medium range weather forecasts in sub-temperate and sub-humid climate of western Himalayas

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ABSTRACT

The medium range weather forecasts were observed and compared for their reliability and profitability for the duration of 1994 to 2010 on seasonal and day wise scale. The forecast verification comprised of the anticipated weather information on six weather parameters, viz. rainfall, cloud cover, maximum temperature, minimum temperature, wind speed and wind direction. The forecast of rainfall, maximum and minimum temperature were realized as high as 93.9, 85.2 and 84.1 percent respectively during the post monsoon (October to December) season compared to 53.2, 71.6 and 74.9 percent in the South West (June to September) monsoon period. The Ratio Score for all the seasons ranged from 57.6 to 83.6 and H K scores ranged from 0.14 to 0.48. For rainfall, highest RMSE of 27.1 was recorded in South West monsoon season indicating lower accuracy. The qualitative forecast revealed higher reliability compared to quantitative forecast. The mean annual usability of rainfall, cloud cover, maximum and minimum temperature were 74.8, 64.7, 62.1 and 63.3 percent respectively. RMSE for minimum temperature was found higher than maximum temperature indicating lower accuracy. For all the seasons, forecast of wind speed showed a high range of accuracy, particularly 100 percent accuracy in post monsoon season. Wind direction was found highly inconsistent in all the seasons with low accuracy. Amongst the medium range weather forecasts for different days, 3 days forecast for the duration of 1994-2000 showed higher accuracy in case of cloud cover, maximum temperature, minimum temperature and wind speed in all the seasons. The increase in accuracy was observed for rainfall and wind direction in case of 4 days forecast. The reliability for 5 days forecast was observed to be lowered in comparison to 3 and 4 days forecast. The medium range forecasts tested for major crops showed profit due to weather forecasts based AAS on farmers' field (2.1 to 5.4%) and university farm (8.9 to 14.7%). The cloud cover forecasts saved 44 to 75 kg fish feed in 100 sq meter area during SW monsoon at Palampur. The temperature forecasts were useful in saving 10 to 20 percent feed in poultry. The farmers' perceptions revealed a fairly good use of forecast for various agricultural activities. Proper rainfall forecasts for drainage of maize, vegetables and pulses saved ₹ 400 per irrigation.

Key words: Cloud cover, Rainfall, Reliability, Temperature, Weather forecast, Wind

Weather conditions during cropping periods play a major role in success or failure of agricultural crop production. 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). The agriculture in Himachal Pradesh utilizes low external inputs and is largely rainfed with 81.2% of the total cultivated area. The economy of the state is highly dependent on agriculture with 19.6% share in Net State Domestic Product (NSDP) of the state during 2005-06 which revealed a significant growth of 6.9% compared to the last decade (Anonymous 2009). The rainfed agro-ecosystem of the state comprising of varied topographical, altitudinal and agroclimatic elements however faces several challenges such as temporal and spatial weather variability to realize optimum productivity. Therefore, favourable weather is desired for sustainable agriculture which minimizes the weather hazards. However, weather cannot be modified except on limited scale but agricultural operations can be reoriented to nearly accurate weather forecasts. Under the changed scenario where agriculture has become highly input and cost intensive, today the weather forecasts relating agriculture are indispensable to reduce the cost of cultivation for crops. Reliable and timely weather forecasts provide significant and useful inputs for precise impact assessment for agricultural activities and proper planning and management in agriculture which is full of uncertainty. Agromet advisory services based on medium

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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). A timely medium range and seasonal forecast could provide 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. In the present study efforts have been made to verify the suitability of the medium range weather forecasts for sub-temperate and sub-humid agroclimate of Himachal Pradesh in relation to its applicability in agricultural management.

MATERIALS AND METHODS

The Palampur, selected region for study is located in district Kangra of Himachal Pradesh and falls in sub-humid and sub-temperate type of climate (Anonymous 2009). Medium Range Weather Forecasts (MRWF) on rainfall, cloud cover, wind speed, wind direction, maximum and minimum temperature received from IMD for 3, 4 and 5 days from 1994 to 2010 for Palampur region of Himachal Pradesh were analysed for validation. The forecasts obtained were compared with daily observed weather data for the respective days from the actual data recorded at agro meteorological observatory situated at Chaudhary Sarwan Kumar Himachal Pradesh Krishi Vishvavidyalaya (CSKHPKV), Palampur. To assess the reliability of different weather parameters of the forecast, different validation methods were used. The forecasts of rainfall, temperature, wind and cloud cover were validated by calculating the error structure. The correct and usable cases were summed up and combined values indicated the percent usability of the forecasts. Root Mean Square Error (RMSE) was calculated for all the parameters. The rainfall forecast was validated with Ratio score indicating the success rate of correct forecast and Hanssen and Kuiper score indicating the skill (H K score).

The validation of weather forecasts was done for four seasons, viz. pre monsoon (March to May), South West monsoon (June to September), post monsoon (October to December) and winter season (January to February) as defined by India Meteorological Department. The validation methods as suggested by Singh *et al.* (1999) were used.

Error structure

Rainfall: Correct ±10%, Usable ±20%,
Temperature: Correct ±1°C Usable ± 2°C,
Wind direction: Correct ±10°, Usable ±30°
Cloud cover: Correct ±1Okta, Usable ± 2 Okta
Wind speed: Correct ±3 kmph, Usable ± 6 kmph

Root Mean Square Error (RMSE)

$$RMSE = [1/N (Pi-Oi)^2]^{1/2}$$

Pi and Oi are predicted and observed values and N is the total number of observations.

Ratio score and Hanssen and Kuiper score

		Observed	
		Rain (Y)	No rain (N)
Forecasted	Rain (Y)	YY	YN
	No rain (N)	NY	NN

Ratio score = (YY+NN)/(YY+NN+YN+NY)
Hanssen and Kuiper score = (YY × NN)–(YN × NY) / (YY+NN) (NY+YN)

The utility of the forecast is defined as the percentage of useful cases of all advisories issued irrespective to the specific field operations. This was assessed by seeking an answer to this effect through pre-tested well designed questions in the questionnaire. The economic impact of the agro advisories based on medium range weather forecast was studied on farmers' field through survey and feedback from the selected representative farmers of the study area to whom Agroadvisory Services (AAS) are provided. The feedback obtained was summarized to draw significant inferences in terms of utility of weather forecasts. The economic impact of AAS was also assessed on the Agronomy farm, fisheries and poultry farm by recording the yield of the crops from two situations, viz. recommended practices and farm operations based on medium range weather forecasting. The practices were imposed on experimental plots of 20 m^2 each for maize, wheat and rice. The final yields were assessed from the plots and percentage increase or decrease due to the medium range forecasts was worked out.

RESULTS AND DISCUSSION

Rainfall

The medium range forecast of rainfall occurrence and amount was compared with the observed values for the period 1994-2010. The performance of rainfall forecast was good in pre monsoon, post monsoon and winter season. The correct and usable cases (usability) for rainfall varied from 20.9 to 89.7 percent over different seasons during 1994 to 2010 (Table 1). Highly accurate, correct and usable cases coincided with post monsoon season (low rainfall season), i.e. 79.7, 91.9 and 93.9% when validated and verified for 3, 4 and 5 days weather forecast respectively. During pre monsoon the usability observed was 70.5, 82.8 and 79.6% for 3, 4 and 5 days average forecast respectively. The lowest usability (36.1 percent) of 5 days weather forecast was observed in South West monsoon season receiving highest amount of rainfall (1800 mm) compared to 4 days (53.2 percent) and 3 day weather forecast (38 percent). The rainfall forecast during pre monsoon and post monsoon season was highly reliable (70 to 90%). Sahu *et al.* (2011) and Lunagaria *et al*. (2008) also recorded lowest percent of rainfall usability

during the monsoon season for Gujarat. The performance of forecast was found average during winter season ranged between 67.5, 76.2 and 77.0 percent usability for 3 days, 4 days and 5 days average forecast respectively.

The RMSE values varied between 4.3 and 27.1 during different seasons with highest RMSE value observed in the South West monsoon season (27.1) corresponding to highest rainfall season when verified for 4 days average (Table 1) indicating high chances of quantitative forecast difference during the season. The lowest RMSE values (4.3 to 7.0) were observed in the post monsoon season signifying least error between observed and forecasted data. The skill of forecast (Ratio score) varied between 57.6 and 83.6% in all the seasons with lowest Ratio score (57.6) in pre monsoon and highest in post monsoon season (83.6) for 4 days average weather forecast validation. South West monsoon and winter season observed ratio score between 62.0 percent and 75.1 percent respectively. Higher values of ratio score indicated a higher amount of precision in forecast. The ratio score was more than 60 percent for all the seasons however, for pre monsoon it was observed 57.6 percent for 5 days weather forecast verification. Singh *et al.* (1999) also obtained similar observations regarding rainfall forecast accuracy for Delhi, Pantnagar and Ludhiana agro-climatic regions. The lowest HK score of 0.14 was observed during post monsoon season and highest (0.48) in the winter season for 4 days weather forecast. The positive HK scores indicated the reliability of forecast to be satisfactory in all the seasons. The correlation coefficients between observed and forecasted rainfall for all the seasons were positive. The qualitative forecast of rainfall during post monsoon had high reliability as compared to other seasons. The pre monsoon showed the lowest correlation (0.09) for 5 days weather forecast and comparatively higher correlation was observed during the winter season (0.34) for four days forecast. The analysis indicated that lowest rainfall (62.7%) of observed rainfall was predicted during South West monsoon season), whereas during post monsoon and winter season higher rainfall of 237.8 percent and 264.3 percent was predicted respectively. Results indicated that lower rainfall was predicted for wet season and higher for dry season.

Cloud cover

The reliability of cloud cover for the duration of 1994-2010 during post monsoon season varied from 57.6 to 81.4 percent followed by South West monsoon varied between 58.8 and 79.7 percent. The usability of cloud cover forecast during pre monsoon period ranged from 60.5 to 76.0 percent and winter season from 46.2 to 69.4 percent (Table 2). The 3 days weather forecast validation indicated accuracy ranged between 65.6 and 81.4 percent for all the seasons. The accuracy of the forecast for post monsoon season was good and ranged between 81.4, 73.4 and 57.6 percent, followed by South West monsoon season 79.7, 58.8 and 63.3 percent for 3 days, 4 days and 5 days average forecast respectively. The pre monsoon forecast was reliable for 3 days average (75.1%) compared to 4 days (69.8%) and 5 days average (60.5%). The winter season cloud cover forecast for 4 days (69.4%) was found reliable compared to 3 days (65.6%) and 5 days (46.2%) average forecast. Lower values of forecasted cloud cover were recorded in winter and pre monsoon seasons and higher values of forecasted cloud cover were recorded in south west monsoon and post monsoon seasons. The overall cloud cover forecast for 5 days average was found to be less accurate and lower usability (46.2 to 63.3%) was obtained. The RMSE value varied between 1.8 and 3.8 with lowest value in post monsoon and the highest value (3.8) was observed during south west monsoon season which was comparable to the winter season (3.7). The correlation coefficients of forecasted and observed cloud cover were

Table 1 Medium Range Weather forecast validation for rainfall for the duration of 1994 to 2010

Seasons	Pre monsoon (March to May)			South West monsoon (June to September)			Post monsoon (October to December)			Winter season (January to February)		
	3 days	4 days	5 days	3 days	4 days	5 days	3 days	4 days	5 days	3 days	4 days	5 days
Accurate and Usable (%)	70.5	82.8	79.6	38.0	53.2	36.1	79.7	91.9	93.9	67.5	76.2	77.0
RMSE	4.6	7.4	8.4	24.3	27.1	24.7	5.1	4.3	7.0	5.5	7.1	11.2
Correlation	0.16	0.22	0.09	0.13	0.17	0.1	0.1	0.09	0.25	0.33	0.34	0.45
Coefficient	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	*
Ratio score	73.0	73.2	57.6	70.5	62.0	71.0	79.5	83.6	69.4	71.3	75.1	60.7
H K Score	0.19	0.27	0.24	0.32	0.25	0.34	0.31	0.31	0.14	0.25	0.48	0.19
Predicted rainfall % of observed	89.8	95.7	203.4	34.3	35.5	62.7	227.4	234.9	237.8	122.8	130.8	264.3

NS: Non-significant, *significant

Table 2 Medium Range Weather forecast validation for Cloud cover for the duration of 1994 to 2010

Seasons	Pre monsoon (March to May)			South West monsoon (June to September)			Post monsoon (October to December)			Winter season (January to February)		
	3 days	4 days	5 days	3 days	4 days	5 days	3 days	4 days	5 days	3 days	4 days	5 days
Correct and Usable (%)	75.1	69.8	60.5	79.7	58.8	63.3	81.4	73.4	57.6	65.6	69.4	46.2
RMSE	2.9	2.6	3.0	2.2	3.8	2.6	1.8	3.6	3.1	2.2	2.7	3.7
Correlation	0.37	0.44	0.24	0.4	0.39	0.46	0.33	0.34	0.11	0.43	0.51	0.10
Coefficient	NS	*	NS	*	NS	*	NS	NS	NS	*	*	NS

NS, Non-significant, *significant

positive and varied from 0.1 to 0.5. Rana *et al.* (2005) also reported similar observations regarding cloud cover for mid hill region of Himachal Pradesh.

Maximum temperature

The accuracy of forecast of maximum temperature during post monsoon season ranged between 42.4 and 85.2 percent followed by Pre monsoon period (30.2 to 82.3%), winter season varied from 52.3 to 73.5 percent and South West season ranged from 31.1 to 71.6 percent (Table 3). The high degree of association between predicted and observed values of temperature was observed in all the seasons for 3 days average forecast (71.6 to 85.2%). Highest usability (85.2%) was observed in post monsoon for 3 days forecast compared to 75.8 percent for 4 days and 42.4 percent for 5 days average. The pre monsoon validation of forecast revealed high usability (82.3%) for 3 days forecast and lowest usability for 5 days (30.2%) forecast. The reliability of forecast was comparable during the south west monsoon season and winter season. The highest RMSE value of 5.5 was observed in pre monsoon. The south west monsoon season and post monsoon season observed RMSE value 4.7 and 4.1 respectively. The RMSE value calculated for winter season was lowest (3.7). The reliability in temperature forecast was found to be more accurate for 3 days average verification. The pre monsoon and post monsoon season showed high degree of association between the predicted and observed values. Amongst seasons, significant correlation was observed between predicted and observed temperature during pre monsoon (0.66 to 0.92) and post monsoon season (0.71 to 0.95) compared to the lowest correlation value for South West monsoon season. The observed and predicted average maximum temperature was compared for all the seasons. The difference in observed and predicted temperature was less for all the seasons which illustrated the high degree of accuracy for temperature. Similar findings regarding temperature forecast were also reported by Lunagaria *et al.* (2009) in their study on validation and usability of medium range weather forecast for Anand region of Gujarat.

Minimum temperature

The accuracy of minimum temperature was observed consistent for all the seasons showing more than 71 percent reliability for 3 days average, whereas in the south west monsoon it was comparatively lower (59.9%). The accuracy during post monsoon season varied between 78.1 and 84.1 percent, followed by winter season ranged between 70.6 and 77.8%, South West monsoon season ranged from 55.9 to 74.9% and pre monsoon period varied from 60.5 to 71.7% (Table 4). The post monsoon recorded highest usability of minimum temperature for 3 days average (84.1%), followed by 4 days (78.1%) and 5 days average (32.5%). The South West monsoon showed average performance where 3 days forecast was lower (59.9%) compared to 4 days average

Table 3 Medium range weather forecast validation for maximum temperature for the duration of 1994 to 2010

Seasons	Pre monsoon (March to May)			South West monsoon (June to September)			Post monsoon (October to December)			Winter season (January to February)		
	3 days	4 days	5 days	3 days	4 days	5 days	3 days	4 days	5 days	3 days	4 days	5 days
Correct and Usable (%)	82.3	61.0	30.2	71.6	68.1	31.1	85.2	75.8	42.4	73.5	63.6	52.3
RMSE	2.2	3.1	5.5	3.5	2.4	4.7	1.8	2.1	4.1	3.1	2.6	3.7
Correlation	0.95*	0.77*	0.71*	0.61*	0.56*	0.07	0.92*	0.76*	0.66*	0.67*	0.64*	0.02
Coefficient	*	*	*	*	*	NS	*	*	*	*	*	NS

NS, Non-significant, *Significant

Table 4 Medium Range -Weather Forecast validation for Minimum temperature for the duration of 1994 to 2010

Seasons	Pre monsoon (March to May)			South West monsoon (June to September)			Post monsoon (October to December)			Winter season (January to February)		
	3 days	4 days	5 days	3 days	4 days	5 days	3 days	4 days	5 days	3 days	4 days	5 days
Correct and Usable (%)	71.7	60.5	23.6	59.9	74.9	30.8	84.1	78.1	32.5	77.8	70.6	38.5
RMSE	2.6	2.8	4.8	2.6	2.1	4.3	1.9	1.8	4.2	2.3	2.2	3.9
Correlation Coefficient	0.91* *	0.74* *	0.63* *	0.66* *	0.46* *	0.28 NS	0.92* *	0.84* *	0.81* *	0.74* *	0.61* *	0.19 NS

NS, Non-significant, *significant

(74.9%) and lowest value was observed for 5 days average (30.8%). The winter season forecast was 77.8, 70.6 and 38.5 percent reliable for 3, 4 and 5 days average forecast respectively. The reliability of forecast for pre monsoon was higher for 3 days (71.7%) compared to 4 days (60.5%) and 5 days (23.6%) forecast. The RMSE values of minimum temperature in general were lower than those of maximum temperature. The mean RMSE of minimum temperature for all the seasons varied between 1.8 (post monsoon) and 4.8 (Pre monsoon pre monsoon). The positive and significant correlation coefficient of the magnitude 0.91 was observed in pre monsoon and post monsoon season compared to south west monsoon (0.66) and winter season (0.74). The south west monsoon season and winter season showed a significant correlation of 0.66 and 0.74 respectively. Rana *et al*. (2005) also concluded similar results regarding usability of temperature forecast for mid hill region of Himachal Pradesh.

Wind speed

The wind speed forecast showed maximum usability ranging between 93.8 to 100 percent. A higher accuracy was obtained when the forecast was validated for 3 days average. The maximum reliability was obtained in the post monsoon season (100 %) followed by pre monsoon (99.2 %), South West monsoon season (98.5%) and the winter season (94.8%). The validation of wind speed forecast revealed 100% reliability in post monsoon season for 3 days forecast compared to 95.8 and 74.7 percent reliability for 4 and 5 days average respectively. The usability of forecast was good in South West monsoon season for 3 days (98.5%), 4 days (95.2%) and 5 days (85.8%) forecast. The forecast for pre monsoon was also higher for 3 days forecast (99.9%) followed by 4 days (96.6%) and 5 days (68.2%) forecast. Chauhan *et al.* (2008) also reported that forecasted wind speed for middle Gujarat region was most accurately comparable with observed wind speed in all the seasons. The RMSE values for the Palampur region varied between 2.1 to 4.6. The correlation coefficients between observed and predicted wind speed were not significant (Table 5). Khichar *et al.* (2010) analysed the reliability and accuracy of weather forecasts for Haryana and observed similar trends in forecast for wind speed.

Wind direction

The forecasted wind direction was compared with the mean wind direction of morning and evening observed in the observatory. The correct and usable cases were observed lower for the post monsoon season 6.3 % for 5 days forecast whereas, it was higher in the winter season with 3 days forecast showed 28.7 percent usability, and 28.6 and 23.3 percent usability for 4 days and 5 days forecast respectively. The usability of forecast during post monsoon season (6.3 to

Table 5 Medium Range Weather Forecast validation for wind speed for the duration of 1994-2010

Seasons	Pre monsoon (March to May)			South West monsoon (June to September)			Post monsoon (October to December)			Winter season (January to February)		
	3 days	4 days	5 days	3 days	4 days	5 days	3 days	4 days	5 days	3 days	4 days	5 days
Correct and Usable (%)	99.2	96.6	68.2	99.0	95.2	85.8	100.0	96.0	74.7	94.8	94.0	74.0
RMSE	2.3	2.9	4.9	2.2	2.0	3.8	2.1	2.0	4.6	3.2	2.7	5.0
Correlation Coefficient	–0.01 NS	0.11 NS	0.14 NS	0.27 NS	–0.01 NS	0.34 NS	0.06 NS	0.02 NS	0.00 NS	0.3 NS	0.22 NS	0.35 NS

NS, Non-significant

Table 6 Medium Range Weather Forecast validation for wind direction for the duration of 1994-2010

Seasons	Pre monsoon (March to May)			South West monsoon (June to September)			Post monsoon (October to December)			Winter season (January to February)		
	3 days	4 days	5 days	3 days	4 days	5 days	3 days	4 days	5 days	3 days	4 days	5 days
Correct and Usable (%)	21.5	23.2	25.9	16.9	22.6	23.4	16.5	24.8	6.3	28.7	28.6	23.3
RMSE	112.9	100.5	76.8	108.2	117.1	78.1	126.4	92.4	75.6	97.2	87.6	74.4
Correlation	–0.12	0.07	–0.08	–0.02	0.05	0.02	0.15	0.03	0.27	0.12	0.03	0.18
Coefficient	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

NS, Non-significant

24.8%) was found comparable with the South West monsoon season (16.9 to 23.4%). RMSE value was higher (117.1) for wind direction in the South West monsoon season. The correlation coefficients were also found non-significant for all the seasons (Table 6). In general a lower degree of wind directions were predicted for all the seasons. Chauhan *et al.* (2008) also observed low accuracy for wind direction with high RMSE values for the middle Gujarat region.

Utility of forecast in farming community

Farmers' perception revealed the usefulness of forecast to the farmer community to a great extent. In the region, majority of farmers rated the usefulness of medium range weather forecast beneficial in making decisions relating to the agricultural operations and felt that forecast could be best utilized to mitigate the impact of climate anomalies. Weather based agro advisory services provided to the farmers could help in proper management of different farm inputs (Rathore *et al*. 2003). The correct cloud cover forecasts were helpful in saving ₹ 350 to 500 (44 to75 kg fish feed) in fishery enterprises in the region during SW monsoon. About 10 to 20 percent feed in poultry was saved due to the higher accuracy in temperature forecast. Medium range rainfall forecasts were also helpful in saving ₹ 400 per irrigation for drainage of maize, vegetables and pulses. Rajegowda *et al.* (2008) in Karnataka and Singh *et al.* (2008) in Hisar also found farmers to have realized higher additional benefit in various crops due to the better irrigation management on the basis of agro advisories issued. The economic benefit accrued in saving agricultural inputs and minimization of loss was also evaluated at the study site by assessing the yield obtained during 2000-2010. The rice, wheat and maize crops showed high economic benefits at the university farm (8.9 to 14.7%) (Table 7) and farmers' fields (4.0 to 5.7%) in four sub-divisions of agroclimatic region due to the advisories and the management strategies suggested at the agro-climatic region (Table 8). The percent gain of AAS farmers over non-AAS farmers was worked out by the difference in return values of AAS farmers and non- AAS farmers dividing the returns of non-AAS farmers and multiplied by hundred. The medium range forecast was found to benefit the farming community. However, during some of the years, loss was encountered in wheat crop due to the failure of forecast during *rabi* season (Table 9). More than 95 percent of the farmers believed that the utility of medium range weather forecast was beneficial for sowing/transplanting information, pest and disease control, fertilizer and manure application, weed control and harvesting.

Farmers to the tune of 93 percent believed that weather forecast provided necessary information regarding vegetable, tea and mushroom production and floriculture. Such findings

Table 7 Increase in Gross returns (₹/ha) and percent increase/ decrease due to AAS for major cereal crops of agro-climatic zone (2000-2010)

Crop	Increase in ₹/ha due to intervention of AASreturns	% increase in net due to in tervention of AAS
Maize	2 320	8.9
Rice	4 110	9.7
Wheat	6 200	14.7

Table 8 Impact of medium range based agroadvisory services on net returns of cereal crops on farmers' field (2002-2010)

Crop	% increase in net returns of crops due to intervention of AAS			
	Baijnath	Palampur	Panchrukhi	Nagrota
Rice	4.4	4.0	5.7	4.7
Maize	2.2	4.4	2.1	-
Wheat	3.9	4.6	3.2	4.5

Table 9 Gross returns (₹/ha) and percent increase/decrease for AAS and Non-AAS farmers

Crop	Gross returns to AAS farmers	Gross returns to Non-AAS farmers	% increase/decrease in returns of AAS over Non-AAS farmers
Maize	40 250	39 600	1.6
Wheat	32 800	34 200	–4.1
Mustard	31 350	29 965	4.6

Table 10 Farmers' perception regarding effectiveness of medium range forecast for agro advisory services in 2009-10

Statement based on benefits of medium range weather forecast and agroadvisory	Agreed by (% Farmers)
Requirement of weather forecasts	100
Television is the best source of information on weather forecasting	84
Listen to Agro-advisory services weather forecasting	97
Benefit from Agro advisory Services	89
Loss from Agro-advisory Services	18
Weather forecasts for more number of days than five days	13
Difference between forecasted and actual weather	100
The forecast for rain and temperature is required	57

regarding the usefulness of medium range weather forecast to the farmers have also been reported by Rana *et al*. (2005) and Ravindrababu *et al*. (2007). Farmers' perception post monsoon effectiveness of forecast revealed that farmers to the tune of 97 percent listened to the forecast provided in the agro advisory bulletins and 89 percent of the farming community earned benefits following the agro advisory services based on weather forecasts. Majority of farmers perceived that agro advisory services are useful and felt necessity for weather forecasting particularly rainfall and temperature for the success of crop (Table 10).

The study clearly showed the high degree of authenticity of forecast of various weather parametres, i.e. rainfall (except during South West monsoon which gave lower accuracy), cloud cover, maximum temperature, minimum temperature, wind speed. Wind direction was found highly inconsistent in all the seasons with lower accuracy. Amongst the medium range forecast validation for different days, 3 days verification showed an increasing tendency of accuracy in case of cloud cover, maximum temperature, minimum temperature and wind speed for all the seasons for 1994-2010. The 4 days forecast showed increasing trend of reliability in case of rainfall and wind direction. The accuracy and reliability for 5 days forecast validation observed to be lowered in comparison to the 3 and 4 days forecast. Higher reliability was observed for qualitative forecast of rainfall. It was also observed that the farmers minimized the crop losses from weather aberrations and realized high benefit with the efficient management practices based on agro advisory services.

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