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Quantitative and qualitative analysis of weather forecast and AAS on Socio-economic status of farmers of South East Bihar

Debjyoti Majumder and Birendra Kumar

Abstract
The weather forecast and actual weather data received from India Meteorological Department, New Delhi were compared to verify the accuracy of rainfall forecast for the year 2016-17 at AMFU centre, Sabour, Bihar. It is apparent that the value of ratio score was higher than (88%) during Pre-monsoon (94%), Post-monsoon (91%) and winter season (89%). The value of threat score was also found maximum during pre-monsoon season (83%). During monsoon, post-monsoon and winter seasons its value were observed 52, 56 and 0 per cent respectively. Out of 91, 119, 90 and 54 cloud cover forecasts received during Pre-monsoon, Monsoon, Post-monsoon and Winter season respectively, 89, 83, 78, 83 per cent were correct in the respective seasons. It was observed that during rainy season, the correctness of forecasts was only 82 per cent while during other seasons the correctness of rain forecast were much higher. The per cent of correctness of wind speed forecast was highest (81%) during winter and lowest during monsoon seasons (49%). For both maximum and minimum temperature it was observed that the correctness of forecast was observed between 78-94 per cent and 81-87 per cent respectively. This forecast directly had an significant role in profit generation among the AAS adaptive farmers whose additional profit was found up to Rs 2164 in maize during *kharif*, Rs. 1,53,000 for vegetables during *Rabi* and Rs. 2,55,000 for Okra during summer.

Keywords: Weather forecast, ratio score, threat score, AAS

Introduction
The Indian agriculture highly depends upon the South Western Monsoon. Over the decade the monsoon have showed wide variability in terms of Intensity, number of rainy days and duration. Srivastava *et al*. (1992) [13] also reported an increasing temperature trends in India on decadal basis. India will also begin to experience greater seasonal variation in temperature, with more warming in winter than summer. Increasing trends of rainfall and minimum temperature in Gangetic plains of Bihar observed by Haris *et al*., 2010 [6]. Bihar is the 12th largest state in India with an area of 94163 sq km. The topography of Bihar is a vast stretch of fertile alluvial plain occupying the Gangetic Valley. Bihar is a definite disaster prone state, especially with floods and droughts. Like flood, drought is also a recurring phenomenon in Bihar. Under such circumstances, the farmers are unaware of the behavioural pattern of monsoon for making decisions in their daily agricultural operations. Weather and climatic information plays a major role before and during the cropping season and if the information on weather is provided in advance can be helpful in inspiring the farmer to organize and activate their own resources in order to maximise the benefits. The National Centre for Medium Range Weather Forecasting (NCMRWF) under the Ministry of Earth Sciences (MoES), Government of India in collaboration with India Meteorological Department (IMD), Indian Council of Agricultural Research and State Agricultural Universities had been providing Agrometeorological Advisory Services (AAS) at the scale of agroclimatic zone to the farming community based on location specific medium-range weather forecast (MRWF) (Singh, 1999) [12]. Since 2007, the entire framework of AAS, developed and successfully demonstrated by NCMRWF, has been relocated at IMD under MoES for extending the service (in operational mode) to districts under these agro-climatic zones. It is now called the Integrated Agrometeorological Advisory Service of MoES. Thus, the AAS set up exhibits a multi-institutional, multidisciplinary synergy to render an operational service for use of the farming community. It have been observed that our present position of crop production has risen significantly by avoiding the ill effect of the climate and judicious use of natural resources.

At the same time agro met advisories played a pivotal role for managing the crop under aberrant weather conditions and ensuring sustainable agriculture in future. The utility of weather forecast depends upon their reliability and applicability at micro level. The emerging ability to provide timely, skillful weather forecasts offers the potential to reduce human vulnerability to weather vagaries (Hansen, 2002) [5]. The major objective of AAS is to benefit the farmers in capitalizing prevailing weather conditions in order to optimize the resource use and to minimize the loss due to harsh/aberrant weather conditions (Venkataraman, 2004) [14]. Agriculturally relevant forecast is not only useful for efficient management of farm inputs but also leads to precise impact assessment (Gadgil, 1989) [3]. The emerging ability to provide timely, skillful weather forecasts offers the potential to reduce human vulnerability to weather vagaries (Hansen, 2002) [5]. The weather forecasting at national level and bi-weekly agro-advisory services at regional level has been critical for the farmers to adjust their production plans in favour of optimum production. However, a people centric group dynamic approach is still lacking (Sharma *et al*., 2008) [11]. Rathore *et al.* (2001) [10] discussed the weather forecasting scheme operational at National Centre for Medium Range Weather Forecast for issuing location specific weather forecast five days in advance. From a farmer's perspective, the forecast value increases if the weather and climate forecasts are capable of influencing their decisions on key farm management operations (Everingham *et al.*, 2002 [1]; Gadgil *et al.*, 2002 [3]; Ingram *et al.*, 2002) [7]. Thus, it becomes essential to relate with the requirements of farmers (Hansen, 2002), understand their needs and give the forecast in appropriate spatial and temporal range (Hammer *et al.*, 2001; Hansen, 2002; Nicholls, 1991; Nicholls, 2000) [4, 5, 8, 9].

Under this context, in this paper we have made an attempt to assess the reliability of forecasts issued by IMD and Bihar Agriculture University biweekly for 17 districts of zone IIIA and IIIB over Bihar after value addition and evaluate the cost economics of implementation of agromet advisory.

Material and Methods

Agroclimatic Zones of Bihar

Bihar is located in the eastern region of India between latitude 24°-20'-10" N to 27°-31'-15" N and longitude 82°-19'-50" E to 88°-17'-40" E. It is an entirely land–locked state, in a Sub Tropical region of the Temperate zone. Based on soil characterization, rainfall, temperature and terrain, four main agro-climatic zones in Bihar have been identified. These are: Zone-I, North Alluvial Plain, Zone II, north East Alluvial Plain, Zone-III A South East Alluvial Plain and Zone-III B, South West Alluvial Plain, each with its own unique prospects. We have considered zone III A and III B comprising of seventeen districts for the present study.

Qualitative and Quantitative Analysis

Meteorologists have developed methods for forecast verification with a variety of purpose in mind for multitude of situations. Here, the term situation relates to consideration such as nature of meteorological variable (Continuous, discrete, ordered/ unordered, bounded/ unbounded). The standard approach is to record the frequencies with which the event was observed and forecasted in a two by- two tables, and then to quantify forecast quality with summary measures of the table. The frequency with which rare events are observed may be low, which increases sampling variation in such measures and creates uncertainty about forecast quality (Ferro Christopher, 2007). Thus, under this context we have tried to verify the forecast values of rainfall during monsoon with the recorded values with different types of statistical tools as briefly described below.

Methods for dichotomous (yes/no) forecasts

A dichotomous forecast says, "yes, an event will happen", or "no, the event will not happen". Rain and fog prediction are common examples of yes/no forecasts. For some applications a threshold may be specified to separate "yes" and "no", for example, winds greater than 50 knots. To verify this type of forecast we start with a contingency table that shows the frequency of "yes" and "no" forecasts and occurrences. The four combinations of forecasts (yes or no) and observations (yes or no), called the joint distribution, are:

Hit – event forecast to occur, and did occur
Miss - event forecast not to occur, but did occur
False alarm - event forecast to occur, but did not occur.
Correct negative - event forecast not to occur, and did not occur

The total numbers of observed and forecast occurrences and non-occurrences are given on the lower and right sides of the contingency table, and are called the marginal distribution.

Table 1: Contingency Table

			Observed	
		Yes	no	Total
Forecast	yes	Hits	false alarms	forecast yes
	no	Misses	correct negatives	forecast no
Total		observed yes	observed no	Total

The contingency table is a useful way to see what types of errors are being made. A perfect forecast system would produce only *hits* and *correct negatives*, and no *misses* or *false alarms*.

Forecast Accuracy (ACC) or Ratio Score or Hit Score

It is the ratio of correct forecast of the total number of forecasts. It varies from 0 to 1 with 1 indicating perfect forecast.

ACC= $\frac{Correct\ Forecast}{Total\ Forecast} = (H+Z)/N = (YY+NN)$/(YY+NN+YN+NY)…. (i)

Where, (N = Z + F + M + H)

Bias score (frequency bias)

$$BIAS = \frac{hits + false\ alarms}{hits + misses}$$ ….. (ii)

False alarm ratio

$$FAR = \frac{false\ alarms}{hits + false\ alarms}$$ … (iii)

Probability of detection (hit rate) – POD is also an important component of the Relative Operating Characteristic (ROC) used widely for probabilistic forecasts.

The Range varies from 0 to 1 with 1 determining the perfect score.

$$POD = \frac{hits}{hits + misses}$$ … (iv)

Threat score (critical success index)

$$TS = \frac{hits}{hits + misses + false\ alarms} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ (v)$$

Hanssen and Kuipers discriminant (true skill statistic, Peirce's skill score)

$$HK = \frac{hits}{hits + misses} - \frac{false\ alarms}{false\ alarms + correct\ negatives} \quad \ldots\ldots\ (vi)$$

(also denoted TSS and PSS)

Heidke skill score (Cohen's)

$$HSS = \frac{(hits + correct\ negatives) - (expected\ correct)_{random}}{N - (expected\ correct)_{random}}$$

$$(expected\ correct)_{random} = \frac{1}{N}\left[\begin{array}{l}(hits + misses)(hits + false\ alarms) + \\ (correct\ negatives + misses)(correct\ negatives + false\ alarms)\end{array}\right] \quad \ldots.\ (vii)$$

Economic Assessment- A Survey was conducted among almost 400 farmers during Kisan Goshti Farmer Awareness programme in different villages of Bhagalpur district and an assessment was amongst the farmers who followed the AAS and the famers who were not aware of the AAS. A cost analysis was done for various *Kharif* and *Rabi* crops. The benefit incurred by the AAS adaptp0ve farmers were compared with AAS Non adaptive farmers during the year 2016-17.

Results and Discussion

Verification and analysis of weather forecast

A five day medium range weather forecast was received from MC, Patna and IMD (Agrimet), Pune on every Tuesday and Friday of the week. The data related to weather forecast of whole year was grouped in four distinct seasons i.e. Pre-monsoon, Monsoon, Post-monsoon and winter for analysis and verification. Both qualitative and quantitative verification analysis was carried out using skill score and critical values for error structure. The correlation co-efficient and root mean squire error have also been worked out of all the four seasons during 2016-17.

Qualitative verification analysis

1. Rain fall forecast verification

For qualitative analysis verification of rainfall forecast, skill score test has been used as suggested by NCMRWF, which are based on 2 x 2 contingencies table. The result of all the four seasons has been presented in table.2.

Table 2: Rainfall prediction trends during different seasons at GKMS Unit of Bihar Agricultural College, Sabour (Year 2016-17)

S. No.	Types of skill score	SEASONS			
		Pre-Monsoon	Monsoon	Post-Monsoon	Winter
1.	Ratio Score	0.941	0.802	0.914	0.891
2.	Bias Score	0.921	0.663	0.544	0.665
3.	Probability of Detection	0.851	0.571	0.514	0.033
4.	False Alarm Ratio	0.033	0.042	0.002	0.046
5.	Threat Score	0.834	0.523	0.565	0.002
6.	Haidke Skill Score	0.787	0.587	0.387	-0.723
7.	Hansen & Kuipper Score	0.832	0.456	0.542	-0.041

It is apparent from the perusal of above table that the value of ratio score was higher all throughout during Pre-monsoon (94%), Post-monsoon (91%) and winter season (89%) and least during Monsoon season (80 %) because this technique of analysis considered NN cases also. The value of ratio score during monsoon season was 80%. This clearly shows that there was better occupancy of forecast during pre and post-monsoon season. Unlikely, for Bias Score estimation method, highest accuracy was observed during the Pre monsoon season (92 %) followed by winter season (67 %), monsoon season (66 %) and least accuracy was observed during post-monsoon season. The probability detection function ranged between 0.03 during winter to 0.85 during pre-monsoon season. The False Alarm ratio was found to have good agreement all throughout the seasons indicating good forecast.

It is to be specially mentioned both for Haidke skill score and Hansen and Kuipper skill score no skill score was observed during Winter (Value tends to zero) whereas good agreement was found during premonsoon season i.e 0.787 and 0.83 respectively.

The value of threat score, which considered only YY cases, was also found maximum during pre-monsoon season (83%). During monsoon, post-monsoon and winter seasons its value were observed 52, 56 and 0 per cent respectively.

2. Analysis verification of other weather parameters

Qualitative analysis verification of some other weather parameters was also carried out using standard statistical procedure for all the four meteorological seasons and has been presented in table.3.

Table 3: Season wise correlation co-efficient and root mean squire error value of different weather parameters.

S. No.	Weather parameters	Seasons (2016-17)							
		Pre-Monsoon		Monsoon		Post-Monsoon		Winter	
		CC	RMSE	CC	RMSE	CC	RMSE	CC	RMSE
1.	Cloud cover	0.5785	2.4385	0.4629	1. 8723	0.5554	2.8643	0.6619	2.0458
2.	Rainfall	0.8574	4.5456	0.3176	21.1475	0.8638	8.9987	0.9203	0.9488
3.	Wind speed	0.7211	2.9303	0.7315	4.1853	1.3469	3.5225	0.3391	3.2119
4.	Wind direction	0.5851	99.9782	0.3697	81.1679	0.3392	105.255	0.5883	99.1220
5.	Max. Temp.	0.9021	1.8681	0.7852	2.6330	0.9803	1.8739	0.8410	2.9486
6.	Min. Temp.	0.8979	2.5214	0.3197	1.7285	0.9589	2.2341	0.8184	2.7769

CC. Correlation, Co-efficient; RMSE- Root Mean Square Error

The perusal of correlation co-efficient and root mean square errors data which were worked out using standard statistical procedure between weather forecast and actual weather prevailed during the same period indicated that the forecasts made by this GKMS were more or less close to correctness excluding wind direction. All observed weather parameters viz, cloud cover, rainfall, wind speed, max. & min. temp and wind direction were found in the line of forecast made in all the four seasons respectively. The RMSE values of wind direction were found too high in all the four seasons to accept any homogeneity in the predicted and observed values. The RMSE value of rainfall during monsoon season was also higher which clearly indicated that forecasts of rain were more or less correct but amount of rain predicted never tallied with observed value of rain occurred.

Quantitative verifications analysis

The quantitative verification analysis worked out between weather forecast made and actual weather prevailed during the same period and has been presented in table 4 (a, b, c, and d). Total numbers of forecasts received during the year 2016-17 were 354 out of which 91 were during pre-monsoon season, 119 were during monsoon season, 90 were during post-monsoon season and 54 were during winter season. These forecasts have been verified by correct, usable and unusable methodology. In this procedure some limits of predicted values of different parameters as suggested by NCMRWF, were used for quantitative verification analysis. Forecast values falling within these limits are recorded as correct and usable and beyond these limit, the forecasts are rated as unusable for meteorological application.

Table 4(a): Weather parameters during pre-monsoon seasons

S. No.	Weather parameters	Pre-monsoon season,2016-17			
		Correct	Usable	Unusable	Total
1.	Cloud cover	69 (76)	12 (13)	10 (11)	91 (100)
2.	Rainfall	82 (90)	05 (5)	04 (04)	91 (100)
3.	Wind speed	47 (52)	15 (16)	29 (32)	91 (100)
4.	Wind direction	40 (44)	13 (14)	38 (42)	91 (100)
5.	Maximum Temperature	73 (80)	10 (11)	08 (9)	91 (100)
6.	Minimum Temperature	64 (70)	15 (16)	12 (13)	91 (100)

Table 4(b): Weather parameters during monsoon seasons

S. No.	Weather parameters	Monsoon season,2016-17			
		Correct	Usable	Unusable	Total
1.	Cloud cover	89 (75)	16 (13)	14 (12)	119 (100)
2.	Rainfall	72 (61)	25 (21)	22 (18)	119 (100)
3.	Wind speed	37 (31)	21 (18)	61 (51)	119 (100)
4.	Wind direction	49 (41)	14 (12)	56 (47)	119 (100)
5.	Maximum Temperature	58 (49)	35 (29)	26 (22)	119 (100)
6.	Minimum Temperature	61 (51)	36 (30)	22 (18)	119 (100)

Table 4(c): Weather parameters during post monsoon seasons

S. No.	Weather parameters	Post-monsoon season,2016-17			
		Correct	Usable	Unusable	Total
1.	Cloud cover	59 (66)	11 (12)	20 (22)	90 (100)
2.	Rainfall	83 (92)	04 (4)	03 (3)	90 (100)
3.	Wind speed	36 (40)	15 (17)	39 (43)	90 (100)
4.	Wind direction	46 (51)	21 (23)	23 (26)	90 (100)
5.	Maximum Temperature	59 (66)	25 (28)	06 (7)	90 (100)
6.	Minimum Temperature	58 (64)	18 (20)	14 (16)	90 (100)

1. Cloud cover

It is clear from the above tables that out of 91, 119, 90 and 54 cloud cover forecasts received during Pre-monsoon, Monsoon, Post-monsoon and Winter season respectively, 89, 83,78 83 per cent were correct in the respective seasons. The correctness of cloud cover ranged between 78 to 89 per cent in different seasons during the year, 2016-17.

Table 4(d): Weather parameters during winter seasons

S. No.	Weather parameters	Winter season,2016-17			
		Correct	Usable	Unusable	Total
1.	Cloud cover	38 (70)	07 (13)	09 (17)	54 (100)
2.	Rainfall	43 (80)	06 (11)	05 (9)	54 (100)
3.	Wind speed	32 (59)	12 (22)	10 (19)	54 (100)
4.	Wind direction	31 (57)	12 (22)	11 (20)	54 (100)
5.	Maximum Temperature	35 (65)	08 (15)	11 (20)	54 (100)
6.	Minimum Temperature	36 (67)	11 (20)	07 (13)	54 (100)

Fig. in ( ) indicated in per cent.

2. Rainfall
Total numbers of rainfall forecasts received during Pre-monsoon, Monsoon, Post-monsoon and winter seasons were 91, 119, 90, 54 respectively. Out of these rain forecasts in the respective seasons 95, 82, 96 and 91 per cent were found to be correct. During rainy season, the correctness of forecasts was only 82 per cent while during other seasons the correctness of rain forecast were much higher because on most of the days there were neither prediction of rain nor it occurred during the said period.

3. Wind speed
During Pre-monsoon, Monsoon, Post-monsoon and winter seasons, total number of wind speed forecasts were 91, 119, 90 and 54 respectively. Out of these forecasts, 68, 49, 57 and 81 per cent were observed to be correct in the respective seasons. The per cent of correctness of wind speed forecast was highest (81%) during winter and lowest during monsoon seasons (49%).

4. Wind direction
Total number of wind direction forecast received during the four meteorological seasons i.e. Pre-monsoon, Monsoon, Post-monsoon and winter was 91, 119, 90 and 54 respectively. Out of these wind direction forecasts, 58, 53, 74, and 79 per cent were correct during the respective seasons, which clearly indicated that on most of the days, forecast of wind direction were beyond and specified limit of ± 50^{O}.

5. Maximum temperatures
In case of maximum temperature, out of 91, 119, 90 and 54 forecasts received during Pre-monsoon, Monsoon, Post-monsoon and winter seasons, 91% during pre-monsoon 78% during monsoon, 94% during post-monsoon and 80% during winter were found correct. This clearly indicated that the percentage of correct forecasts were in the range of 78- 94 in the respective seasons.

6. Minimum temperature
Similarly, in case of minimum temperature forecasts, out of 91, 119, 90 and 54 forecasts received during the respective season, 86, 81, 84 and 87 were correct and it indicating 81-87 percent correctness in the respective seasons.

Economic Impact of Agro met Advisory Services
Agromet advisories services gives useful scientific information to the farmers of this region in deciding their planning and budgeting for weather-agro management operations to achieve maximum benefit or outcome from predicted weather forecast served to them periodically or every days on need based by Agromet Advisory Services Unit comprising of eminent scientists of different disciplines of Bihar Agricultural College, Sabour.
Table 5.0 indicated that in case of *kharif* paddy and maize monetary value of saving was estimated as Rs. 2132/- and Rs.2464/- per hectare respectively. The estimated loss to the non-adoptive farmers who did not follows the Advice rendered by agromet advisories served by this centre was estimated as 164 kg and 176 kg per hectare in paddy and maize crop respectively under this agro-climatic zone. In case of *Rabi* season wheat, maize, gram, lentil and cauliflower monetary value of saving was estimated Rs.7200, Rs.3472, Rs.10200, Rs.7344, Rs.1, 53, 000 per hectare respectively. The grain yield losses of wheat, maize, gram, lentil and cauliflower the non-adoptive farmers who did not follow the agromet advisories were 450 kg, 248 kg, 120 kg,108 kg and 1.7 mt per hectare respectively.
Similarly, in case of summer season moong, okra, mango, litchi and banana were cultivated and the benefit to growers were estimated as Rs.3628, Rs.2,55,000 for moong and okra respectively and Rs.2760, Rs.3525 and Rs.60 per tree from mango, litchi and banana crop respectively.

Table 5: Monetary gains accrued to progressive farmers during the year 2016-17

Seasons	Crop grown by the farmers	Mean productivity realized in kg $^{-1}$ or Mt of grains /fruits ha^{-1}		Additional Production gains by adoptive farmers(kg ha^{-1}) or Matric tonnes	Price Rs. kg^{-1} or MT	Additional income Rs. ha^{-1}
		AAS adoptive farmers	AAS Non-adoptive farmers			
Kharif	Paddy	1680	1516	164	13	2132
	Maize	2798	2622	176	14	2464
Rabi	Wheat	2318	1868	450	16	7200
	Maize	2812	2564	248	14	3472
	Gram	764	644	120	85	10200
	Lentil	692	584	108	68	7344
	Vegetable (cauliflower)	16.3 MT	14.6 MT	1.7MT	09	1,53,000
Summer	Moong	0629	0516	113	56	6328
	Vegetable (Okra)	13.0 MT	11.3 MT	1.7MT	15	2,55,000
	a. Mango/tree (Big)	258 kg	189 kg	69 kg	40	2760
	b. Litchi/tree (Big)	146 kg	111 kg	35 kg	95	3325
	c. Banana/tree	16 dozen	12 dozen	4 dozen	15	60

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References
1. Everingham YL, Muchow RC, Stone RC, Inman BG, Singels A, Bezuidenhout CN. Enhanced risk management and decision-making capability across the sugarcane industry value chain based on seasonal climate forecasts. Agric. Syst. 2002; 74(3):459-477.
2. Ferro Christopher AT. Verification for deterministic forecasts of rare, binary events. Walker Institute, Department of Meteorology, University of Reading, 2007.

3. Gadgil S. Monsoon variability and its relationship with agricultural strategies. Paper presented at International symposium on climate variability and food security in developing countries. Feb 5-7, 1987, New Delhi, India, 1989, 249-267.
4. Hammer GL, Hansen JW, Phillips JG, Mjelde JW, Hill H, Love A *et al*. Advances in application of climate prediction in agriculture. Agric. Syst. 2001; 70(2-3):515-553.
5. Hansen JW. Realizing the potential benefits of climate perdition to agriculture and challenges. Agric. Systems. 2002; (74):329-330.
6. Haris AA, Chhabra V, Biswas S. Rainfall and temperature trends at three representative agro ecological zones of Bihar. J Agrometeorology. 2010; 12(1):37-39.
7. Ingram KT, Roncoli MC, Kirshen PH. Opportunities and constraints for farmers of West Africa to use seasonal precipitation forecasts with Burkina Faso as a case study. Agric. Syst. 2002; 74(3):331-349.
8. Nicholls N. Advances in long-term weather forecasting. In Climatic Risk in Crop Production: Models and Management in the Semi-Arid Tropics and Subtropics, CAB International, Wallingford, CT, 1991, 427-444.
9. Nicholls N. Opportunities to improve the use of seasonal climate forecasts. In Applications of Seasonal Climate Forecasting in Agricultural and Natural Ecosystems: The Australian Experience (Eds Hammer, G. L., Nicholls, N. and Mitchell, C.), Kluwer, Dordrecht, The Netherlands, 2000, 309-327.
10. Rathore LS, Gupta A, Singh KK. Medium range weather forecasting and agricultural production. Journal of Agric. Physics. 2001; 1(1):43.
11. Sharma SK, Kothari AK, Sharma RK, Jain PM. Capitalizing on agro-advisoty services for higher productivity in rainfed Agroecosystem – A case study. J Agrometeorology. (Special issue- Part 1), 2008, 219-224.
12. Singh SV, Rathore LS, Trivedi HKN. Verification of medium range weather forecasts, (in) Guide for Agrometeorological advisory services. National Centre for Medium Range. Weather Forecasting, Department of. Science and Technology, Govt. of India, 1999, 73-81.
13. Srivastava HN, Denian BN, Dikshit SK, Rao GSP, Singh SS, Rao KR. Decadal trends in climate over India. Mausam. 1992; 43:7-20.
14. Venkataraman. Climatic characterization of crop productivity and input needs for agro meteorological advisory services. J Agrometeorology. 2004; 6(11):98-105.