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Estimation of cotton yield based on weather parameters of Banaskantha district in Gujarat state

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ABSTRACT

The present investigation was undertaken to identify the quantitative relationship between weather parameters and district level yield of cotton and to develop preharvest forecast models for cotton yield. For this purpose 32 years weather and crop yield records of Banaskantha district were collected. It was found that the 26 week crop period model (using original weather variables, week wise approach) was recommended for pre harvest forecast due to higher R^2 value and lower simulated forecast error. The time trend, maximum temperature, morning and evening relative humidity have significantly affected on crop yield.

Key words: Cotton, prediction equation, forecasting, weather variables.

Timely and reliable forecast of crop yield is of great importance for monsoon dependent country like India, where the economy is mainly based on agricultural production. Climate is closely linked with crop growth, development and production and affected by both long term meteorological factors (the climate) and short term meteorological events (the weather). Crop weather models have become key to predict crop yield in a vast country like India for planners and policy makers. Cotton is an important cash crop grown under both rainfed and irrigated conditions in India. Banaskantha district is located in North Gujarat and North West Gujarat Agro climatic Zones. The average productivity of cotton is 325 kg ha^{-1} occupying total area of about 0.17 lakh ha. The weather variables like rainfall, maximum and minimum temperature, relative humidity and sunshine hours affect crop growth and development in different ways and at different times during the growth cycle of the crop The relationship between crop yield and weather parameters can be identified with the help of multiple regression models (Agrawal and Mehta, 2001).

MATERIALS AND METHODS

The present study was undertaken to investigate the feasibility of estimating the yield of cotton crop based on weather variables using past weather records for Junagadh district **(**Dubey *et al.,*1995 and Singh and Singh, 1988). For this purpose, the yield data of cotton crop for the 32 years (1975-76 to 2006-07) of Banaskantha district were collected from Season and Crop Report published by Directorate of Agriculture, Gujarat State(Anonymous, 2006-07). The corresponding data on weather parameters were collected from meteorological observatory situated in Junagadh, Anand and Sardarkrushinagar Agricultural Universities. The data on weather variables were collected from 22nd meteorological standard week (MSW) to 47th standard week of each year. Four models were fitted by using original weather variables based on week wise approach considering upto 17, 20, 23 and 26 weeks of crop period. The time trend variable was included in this analysis as an explanatory variable.

The variables used in this study were weekly average of,

Y : Average cotton yield of the district in kg/ha.
T : Time trend, year number.
X_1 : Rainfall (m.m.)
X_2 : Maximum temperature (^{0}C)
X_3 : Minimum temperature (^{0}C)
X_4 : Morning relative humidity (%)
X_5 : After noon relative humidity (%)
X_6 : Sunshine hours.

The mathematical expression used for the analysis is given by the equation, $Y = A + \sum_{i=1}^{p} \sum_{j=1}^{w} a_{ij} X_{ij} + bT$

Where,

Y = Average cotton yield of district kg ha^{-1}

A = Constant

X_{ij} = Observed value of i^{th} weather variable in j^{th} week I = 1,2,...p=6 and j= 1,2,...w= 17, 20, 23, 26

T = Year number included to correct for the long term upward or downward trend in yield (T= 1,2,... t= 32)

a_{ij}, and b = are partial regression coefficients associated with each $\mathbf{X_{ij}}$, and time trend respectively**.**

Table1: Variables included in the model week wise approach up to 26 weeks crop period.

Meteo. Std. week No. (MSW)	Crop week No.	Rain fall (mm)	Temperature (^{0}C)		Relative humidity (%)		Sunshine hours/day
			Max.	Min.	M	E	
		X_{1j}	X_{2j}	X_{3j}	X_{4j}	X_{5j}	X_{6j}
22	01	X_{101}	X_{201}	X_{301}	X_{401}	X_{501}	X_{601}
23	02	X_{102}	X_{202}	X_{302}	X_{402}	X_{502}	X_{602}
24	03	X_{103}	X_{203}	X_{303}	X_{403}	X_{503}	X_{603}
25	04	X_{104}	X_{204}	X_{304}	X_{404}	X_{504}	X_{604}
26	05	X_{105}	X_{205}	X_{305}	X_{405}	X_{505}	X_{605}
27	06	X_{106}	X_{206}	X_{306}	X_{406}	X_{506}	X_{606}
28	07	X_{107}	X_{207}	X_{307}	X_{407}	X_{507}	X_{607}
29	08	X_{108}	X_{208}	X_{308}	X_{408}	X_{508}	X_{608}
30	09	X_{109}	X_{209}	X_{309}	X_{409}	X_{509}	X_{609}
31	10	X_{110}	X_{210}	X_{310}	X_{410}	X_{510}	X_{610}
32	11	X_{111}	X_{211}	X_{311}	X_{411}	X_{511}	X_{611}
33	12	X_{112}	X_{212}	X_{312}	X_{412}	X_{512}	X_{612}
34	13	X_{113}	X_{213}	X_{313}	X_{413}	X_{513}	X_{613}
35	14	X_{114}	X_{214}	X_{314}	X_{414}	X_{514}	X_{614}
36	15	X_{115}	X_{215}	X_{315}	X_{415}	X_{515}	X_{615}
37	16	X_{116}	X_{216}	X_{316}	X_{416}	X_{516}	X_{616}
38	17	X_{117}	X_{217}	X_{317}	X_{417}	X_{517}	X_{617}
39	18	X_{118}	X_{218}	X_{318}	X_{418}	X_{518}	X_{618}
40	19	X_{119}	X_{219}	X_{319}	X_{419}	X_{519}	X_{619}
41	20	X_{120}	X_{220}	X_{320}	X_{420}	X_{520}	X_{620}
42	21	X_{121}	X_{221}	X_{321}	X_{421}	X_{521}	X_{621}
43	22	X_{122}	X_{222}	X_{322}	X_{422}	X_{522}	X_{622}
44	23	X_{123}	X_{223}	X_{323}	X_{423}	X_{523}	X_{623}
45	24	X_{124}	X_{224}	X_{324}	X_{424}	X_{524}	X_{624}
46	25	X_{125}	X_{225}	X_{325}	X_{425}	X_{525}	X_{625}
47	26	X_{126}	X_{226}	X_{326}	X_{426}	X_{526}	X_{626}

Table 2: Regression equations for 17 - week crop period of Banaskantha district (week wise approach)

Variables in the equation	Models for different years			
	Model-I	Model-II	Model-III	Model-IV
	28 years	29 years	30 years	31 years
Constant	640.92	694.49	702.89	709.83
T	1.72	3.76*	4.36**	4.46**
X_{213}	-23.67**	-29.08**	-30.49**	-30.84**
X_{516}	3.79**	4.86**	5.25**	5.28**
X_{612}	27.05**	37.65**	40.01**	40.33**
S. E.	44.91	52.88	53.63	52.66
R^2 (%)	77.45	83.33	88.91	91.42

*Significant at 5% level. ** Significant at 1% level.

Table 3: Simulated forecast values for 17-week crop period of Banaskantha district (week wise approach)

Year	Observed yield (kg ha^{-1})	Predicted values (kg ha^{-1})			
		Model-I 28 years	Model-II 29 years	Model-III 30 years	Model-IV 31 years
2003-04	680	467 (31.32)	--	--	--
2004-05	722	506 (29.92)	633 (12.33)	--	--
2005-06	680	504 (25.88)	629 (7.50)	664 (2.35)	--
2006-07	879	634 (27.87)	795 (9.56)	840 (4.44)	847 (3.64)

Figures in parenthesis are per cent deviation from observed yield.

Table 4: Regression equations for 20-week crop period of Banaskantha district (week wise approach)

Variables in the equation	Models for different years			
	Model-I 28 years	Model-II 29 years	Model-III 30 years	Model-IV 31 years
Constant	722.96	777.61	786.46	783.67
T	3.67**	5.56**	6.04**	6.00**
X_{120}	-2.10**	-2.44**	-2.53**	-2.52**
X_{213}	-26.91**	-31.60**	-32.68**	-32.54**
X_{516}	3.91**	4.76**	5.02**	5.01**
X_{612}	26.94**	35.06**	36.63**	36.53**
S. E.	35.11	41.64	41.97	41.14
R^2 (%)	85.07	90.10	93.48	94.96

*Significant at 5% level. ** Significant at 1% level.

Table 5: Simulated forecast values for 20-week crop period of Banaskantha district (week wise approach)

Year	Observed yield (kg ha^{-1})	Predicted values (kg ha^{-1})			
		Model-I 28 years	Model-II 29 years	Model-III 30 years	Model-IV 31 years
2003-04	680	509 (25.15)	--	--	--
2004-05	722	553 (23.41)	659 (8.72)	--	--
2005-06	680	556 (18.24)	661 (2.79)	687 (1.03)	--
2006-07	879	700 (20.36)	835 (5.01)	868 (1.25)	865 (1.59)

Figures in parenthesis are per cent deviation from observed yield.

Table 6: Regression equations for 23 - week crop period of Banaskantha district (week wise approach)

Variables in the equation	Models for different years			
	Model-I 28 years	Model-II 29 years	Model-III 30 years	Model-IV 31 years
Constant	773.87	834.32	843.55	827.84
T	4.18**	5.75**	6.17**	5.96**
X_{120}	-2.35**	-2.71**	-2.79**	-2.74**
X_{213}	-28.25**	-32.18**	-33.14**	-32.49**
X_{516}	4.08	4.76**	4.99**	4.94*
X_{523}	-0.67**	-0.95**	-0.97**	-0.93**
X_{612}	28.69**	35.25**	36.63**	36.15**
S. E.	32.90	36.98	37.26	36.82
R^2 (%)	87.48	92.53	95.07	96.13

Table 7: Simulated forecast values for 23-week crop period of Banaskantha district (week wise approach)

Year	Observed yield (kg ha^{-1})	Predicted values (kg ha^{-1})			
		Model-I 28 years	Model-II 29 years	Model-III 30 years	Model-IV 31 years
2003-04	680	543 (20.15)	--	--	--
2004-05	722	580 (19.67)	666 (7.76)	--	--
2005-06	680	596 (12.35)	686 (0.88)	710 (4.41)	--
2006-07	879	745 (15.24)	862 (1.93)	891 (1.37)	878 (0.11)

Figures in parenthesis are per cent deviation from observed yield.

RESULTS AND DISCUSSION

In order to investigate the effect of weekwise weather variables on the cotton yield, the variables which appeared in the equation and had significant partial regression coefficient were considered to have influence on the cotton production. The results are presented in two parts for different models. First part deals with fitted regression equations. Second part deals with their corresponding simulated forecasts for subsequent years not included for obtaining the regression equations (Varmola *et al.*, 2004).

The result related to 17 week period model, indicated that time trend, afternoon relative humidity of 16th week **(X_{516})** and sunshine hours of 12th week **(X_{612})** significantly and positively influenced the yield of cotton. The influence of maximum temperature of 13th week **(x_{213})** was negative. The weeks correspond to flowering stage of cotton crop. The variation explained by these variables in fitted models of 17 week period data ranged from 77.45% to 91.42% (Table 2). The simulated forecasts of subsequent years not included in obtaining regression equations, showed 2.35 to 31.32 per cent deviation from the actual district average cotton yield (Table 3).

The results presented in case of 20 week period model, revealed that variables such as time trend, afternoon relative humidity of 16th week **(X_{516})** and sunshine hours of 12th week **(X_{612})** have positive and significant effect on yield. The rainfall of 20th week **(X_{120})** and maximum temperature of 13th week **(X_{213})** had negative influence and significantly predicted the

Table 8: Regression equations for 26 - week crop period of Banaskantha district (week wise approach)

Variables in the equation	Models for different years			
	Model-I 28 years	Model-II 29 years	Model-III 30 years	Model-IV 31 years
Constant	1191.40	1283.81	1299.92	1244.61
T	5.18**	6.27**	6.61**	6.20**
X_{120}	-2.98**	-3.28**	-3.36**	-3.23**
X_{213}	-32.40**	-35.37**	-36.17**	-34.81**
X_{516}	3.98**	4.39**	4.56**	4.49**
X_{523}	-1.07**	-1.30**	-1.33**	-1.22**
X_{612}	33.07**	37.70**	38.82**	37.81**
X_{625}	-30.41**	-34.42**	-35.11**	-33.06**
S. E.	23.58	25.93	26.31	27.44
R^2 (%)	93.87	96.49	97.65	97.94

*Significant at 5% level. ** Significant at 1% level.

Table 9: : Simulated forecast values for 26-week crop period of Banaskantha district (week wise approach)

Year	Observed yield (kg ha^{-1})	Predicted values (kg ha^{-1})			
		Model-I 28 years	Model-II 29 years	Model-III 30 years	Model-IV 31 years
2003-04	680	590 (13.24)	--	--	--
2004-05	722	620 (14.13)	654 (9.42)	--	--
2005-06	680	654 (3.82)	717 (5.44)	736 (8.24)	--
2006-07	879	856 (2.62)	941 (7.05)	966 (9.90)	938 (6.71)

Figures in parenthesis are per cent deviation from observed yield.

yield. The weeks correspond to flowering to boll formation stages of cotton crop. The coefficient of determination (R^2) varied from 85.07 to 94.96% (Table 4). The simulated forecasts showed deviation from observed yield ranged from 1.03 to 25.15 per cent (Table 5).

The result of 23 week period model revealed that out of 157 explanatory variables included in the analysis, 5 weather variables and time trend significantly affected on the yield of cotton crop. The partial regression coefficients corresponding to the variables time trend, afternoon relative humidity of 16th week **(X_{516})** and sunshine hours of 12th week **(X_{612})** were observed to be positive and significant. The partial regression coefficients corresponding to the variables, rainfall of 20th week **(X_{120})**, maximum temperature of 13th week **(X_{213})** and afternoon relative humidity 23rd week **(X_{523})** were found to be negative and significant. The weeks correspond to flowering to boll formation stages of cotton crop. The variation explained by these variables in fitted models of 23 week period data were more than 96 per cent (Table. 6). The simulated forecasts obtained from these prediction equations, showed 0.11 to 20.15 % deviations from the recorded yields of the district (Table. 7).

The results presented in case of 26 week period model, revealed that variables such as time trend, X_{516} and X_{612}

have significantly and positively affected the yield. The parameters $\mathbf{X_{120}}$, $\mathbf{X_{213}}$, $\mathbf{X_{523}}$ and $\mathbf{X_{625}}$ have negatively influenced the yield of cotton. The weeks correspond to flowering to ripening stages of cotton crop. The variation explained by these variables in fitted models of 26 week period data ranged from 93.87% to 97.94% (Table 8). The simulated forecasts obtained from these prediction equations, showed 2.62 to 14.13 per cent deviation from the recorded cotton yields of the district (Table 9).

The perusal of the results of Banaskantha district indicated that the approaches under study, the 26 weeks crop period model (using original weather variables, week wise approach) could be suggested as a pre-harvest forecast model. The variation explained by this model was very high (> 97%) and simulated forecast error was less than 15%.This model could be utilized for pre-harvest forecast 4 weeks in advance of harvesting of cotton crop.

The recommended model for Banaskantha district is,

$$Y = 1244.61 + 6.20^{**} T - 3.23^{**} X_{120} - 34.81^{**} X_{213} + 4.49^{**} X_{516} - 1.22^{**} X_{523} + 37.81^{**} X_{612} - 33.06^{**} X_{625}$$

$$(R^2 = 97.94\%)$$

CONCLUSION

For Banaskantha district, the 26 weeks period model could be preferred for forecasting yield before four weeks in advance of expected harvesting period of cotton crop. The fitted model indicated that the effect of time trend was positive and significant on cotton yield, suggesting the influence of technology in this district. The afternoon relative humidity of 16th week and sunshine hours of 12th week were beneficial to improve the productivity of cotton yield. The rainfall of 20th week, maximum temperature of 13th week, after noon relative humidity of 23th and sunshine hour of 25th week were found to have adversely affected cotton yield in the district. Detrimental effect of the rainfall was observed in Banaskantha district, during 20th week **($\mathbf{X_{120}}$)**, which corresponded to boll formation stage.

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