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Development of Statistical Model for Pre-Harvest Yield Prediction of *Kharif* Groundnut in Rajkot District of Gujarat State

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Abstract: ***Crop production and productivity depend on climate in general and weather in particular. The productivity of the crop depends on soil characteristics and weather conditions during season. The present study of forecasting groundnut yield for Rajkot district based on weekly average data of weather parameters like maximum and minimum temperature, morning and afternoon relative humidity, sunshine hours and past year total rainfall over a period of 35 years (1976-2010) for Rajkot district. The approach used for forecasting yield was original weather variables and week wise approach. The time trend was include as an explanatory variable. For this district, the model of 14 weeks period (week wise approach) was selected. The model for Rajkot district can be used for providing pre-harvest forecast four weeks before expected harvest. The result of the study shows that model selected for Rajkot district for pre-harvest forecast explain more than 75 percent variation.***

Keywords: Groundnut, Regression, Statistical model, Weather Parameters, Weather Forecasting.

Introduction

Indian economy is mainly based on agriculture. India has made considerable progress in agriculture since independence in terms of production, productivity and area under cultivation in respect of many crops. Indian agriculture has performed impressively in terms of increasing productivity and intensity of cultivation. The overall growth of the Indian economy depends upon the performance of agriculture, which depends, quite a lot, upon the weather conditions every year and yield of most of the crops are fairly below the levels of these achieved.

Groundnut (*Archis hypogaea*) is an important oilseed crop. The oil content of kernels ranges from 40-50 per cent and is extensively used for cooking purposes. Oil is a rich source of vitamin A, B and E. It contains on an average 40.1 per cent fat and 25.3 per cent protein which is about 1.3 times higher than meat, 2.5 times higher than eggs and 8 times higher than fruits. Groundnut kernels are used in the roasted form for culinary purposes. It is an important source of vegetable oil and also an important source of food, feed, nutrition and fodder. Groundnut is also called as the “King” of oilseeds or “Wonder nut” and “Poor men’s cashew nut”.

In India, it is grown on about 4.93 million hectare with production of 5.64 million tonnes and productivity is about 1144 kg/ha. In Gujarat, it is grown on 1.82 million hectare with production of 1.76 million tonnes and productivity is 964 kg/ha. (Anonymous, 2010). India has been cultivating groundnut since the late

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19th century, gradually became the major groundnut producing country in the world within a span of 5-6 decades. India occupied the second position for area and production of groundnut in the world. India holds a premier position in oilseeds scenario accounting for 29 per cent of total global area and 13 per cent of production.

The groundnut crop is grown in areas receiving the rainfall between 500 and 1250 mm and performs better in the sandy loam and loamy soils. In Saurashtra, groundnut is grown in black calcareous soils. The major groundnut growing districts in Gujarat are Junagadh, Jamnagar, Amreli, Bhavnagar, Rajkot, Mehsana and Bhuj. In Gujarat, groundnut is mainly grown in *Kharif* (June-October) season and Junagadh is the most productive among all the districts (Sahu et al. 2004). In Saurashtra region about 80 per cent of the crop is grown under rain-fed condition and due to vagaries of monsoon the year-to-year yield fluctuations are more.

The weather variables like rainfall, maximum and minimum temperature, relative humidity and sunshine hours affect growth and development in different ways and at different times during the growth cycle of the crop. The relationship between crop yields and weather parameters can be identified with the help of multiple regression models (Agrawal *et. al*,, 2001).The effects of the weather variables also differed within the crop stage of Rajkot district, suggesting thereby smaller period than a crop stage improves the predictability of groundnut productivity. This was the reason that in week wise approach, the relative performance of predictability was found higher in Rajkot district. The pre-harvest forecasting model, which accounted for at least 75 per cent of total variation in groundnut yields and the one that gave earliest forecasts, having narrow deviations from the reported yields of the Rajkot district, was proposed as pre-harvest forecast model of groundnut crop. Development of the statistical models for forecasting of yield and production of groundnut on Rajkot district levels in Saurashtra region.

Materials and Methods

Considering the specific objectives under research study, Rajkot district was selected based on last ten year average yield of groundnut. The area, production and productivity of groundnut crop for the period of past 35 years (1976 to 2010) were collected from Department of Economics, JAU, Junagadh.

Weather Parameters:

The corresponding data on weather parameters were collected from the weather stations situated in Rajkot districts. For this study monthly and weekly average weather data were collected for the growing season of groundnut crop.

Y: Average groundnut yield of the district in kg/ha.
T: Time trend, year number included to correct for upward or downward trend in yield.
X_1: Minimum temperature (^{0}C)
X_2: Maximum temperature (^{0}C)
X_3: Morning relative humidity (%)
X_4: After noon relative humidity (%)
X_5: Sunshine hours (hrs)
X_6: Total rainfall of past year (mm)

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The details on crop season of groundnut, meteorological standard weeks and physiological stages of groundnut crop are given in Table 1.

Analysis was carried out to formulate a relationship for predicting the groundnut yield (**Y**) of the district by investigating the influences of important weather factors (X_i's) on the groundnut crop. Due to technological advancement, the time trend (**T**) was assumed to be present, therefore time variable was also considered as one of the independent variables in the study.

In week wise approach, the weekly average weather data were used as per original scales. The data on weather variables were collected from 24th meteorological standard week (MSW) to 40th standard week of the year. With a view to assess the accuracy and capability of earlier forecasts at an interval of weeks, four models was fitted, considering up to 11, 12, 13 and 14 weeks after sowing during the crop period. The details of variables included in model up to 18 weeks crop period are given in Table. 2. The time trend variable was included in this analysis as an explanatory variable.
The mathematical expression of this approach,

$$Y = A_0 + \sum_{i=1}^{p}\sum_{j=1}^{w} a_{ij}X_{ij} + bR + cT$$

Where, Fisher, R.A. (1924).
Y = Average groundnut yield of district in kg/ha
$\mathbf{A_0}$ = Constant
$\mathbf{X_{ij}}$ = Observed value of ith weather variable in jth week i = 1,2,... p = 6 and j = 1,2,... w = 12, 13, 14, 15
R = Total rainfall of past season of the district in mm.
T = Year number included to correct for the long term upward or downward trend in yield (T = 1, 2 ... t = 30**)**
$\mathbf{a_{ij}}$, **b** and **c** are partial regression coefficients associated with each $\mathbf{X_{ij}}$, rainfall and time trend **(T)** respectively.

Selection of Variables:

For selecting the best regression equation with significant independent variables among number of independent variables the stepwise regression procedure was adopted (Draper and Smith, 1966). The best regression equation for predictive purpose should be such as would include as many independent variables as possible, but at the same time, reject all those variables which do not contribute significantly to the prediction model. There is no unique statistical procedure to compromise between these two extremes, but stepwise regression analysis procedure which is generally applied under such circumstances and considered as the best selection procedure. Though, the number of observations are less than the number of variables, the technique was adopted by turn to all the independent variables, along with a sub set of 24 to 28 variables to 35 years data (with F= 3, 2 to enter and remove) Further, this procedure was repeated for those entered explanatory variables in such a way that maximum coefficient of determination could be achieved**.**

Finally, selected explanatory variables in each model were used for regression analysis**.** The least squares solution for the model provided a set of normal equations to be solved for the 'k' partial regression coefficient and tested for their significance by 't' test and the regression sum of squares by the 'F' test (Snedecor and Cochran, 1967). Four sets of the multiple linear regression equations were obtained separately for 31 to 34 years data for each approach and predicted the yield of groundnut.

Simulated Forecast Model:

Using these fitted prediction equations, simulated forecasts were obtained for subsequent years, which were not included in the model development. The per cent deviations of these forecasts from the reported yields were worked out to assess the suitability of these equations as pre-harvest forecast models**.** Finally, the model which provided the early forecast and accounted more than 75 per cent of the total variation and which did not deviate much more (< 7 %) from the observed yields of the district, were considered as pre-harvest forecasts models.

RESULT AND DISCUSSION

The result presented in case of 11 week period model, revealed that variables such as time trend (T), 9th week of morning relative humidity (X_{309}), 4th & 6th week of afternoon relative humidity (X_{404}, X_{406}), 2nd week of sunshine hours (X_{502}) and 1st & 2nd week of rainfall (X_{601}, X_{602}) were significantly and positively affected but in case of 1st week of minimum temperature (X_{101}) and 10th week of afternoon relative humidity (X_{410}) were negatively influenced on yield of groundnut. The weeks correspond to sowing and podding stages of the groundnut crop. The period data ranged from 68.34 to 72.97% (Table. 3). The simulated forecasts obtained from these prediction equations, showed 8.38 to 55.19 per cent deviation from the recorded groundnut yield of the Rajkot district (Table. 4).

In case of 12 week crop period, in the Table. 5, result suggested that there is a positive and significant effect of time trend (T), afternoon relative humidity of 6th , 8th & 10th week (X_{406}, X_{408}, X_{410}) and rainfall of 1st & 2nd week (X_{601}, X_{602}) in all four models. The negative and significant effect influence on groundnut crop is observed in case of minimum temperature of 1st week (X_{101}) and maximum temperature of 5th week (X_{205}) corresponding to the sowing and vegetative stages of the crop. The coefficient of determination (R^2) varied from 59.12 to 63.99 % and the predicted values (Table. 6) showed 0.46 to 27.43 per cent deviation from recorded yield of Rajkot district.

The result of the 13 week period model showed that, the effect of time trend (T), afternoon relative humidity of 6th & 10th week (X_{406}, X_{410}), bright sunshine hours of 7th week (X_{507}) and rainfall of 1st & 2nd (X_{601}, X_{602}) were positive and significant. The negative and significant effect influence on groundnut crop is observed in case of minimum temperature of 1st week (X_{101}), maximum temperature of 9th week (X_{209}) and sunshine hours of 12th week (X_{512}). The weeks correspond to sowing, flowering, podding and maturity stages of groundnut. The coefficient of determination varied from 57.59 to 59.18 % (Table. 7) and the deviation in predicted values varied from 0.35 to 44.09 per cent (Table. 8).

The analyzed result of 14 week period model is presented in Table. 9. The result revealed that out of all the variables the effect of time trend (T), afternoon relative humidity of 5th, 6th, 8th & 10th week (X_{405}, X_{406}, X_{408}, X_{410}), bright sunshine hours of 12th week (X_{512}) and rainfall of 1st & 2nd (X_{601}, X_{602}) were positive and significant. The negative and significant effect influence on groundnut crop is observed in case of minimum temperature of 1st week (X_{101}) and maximum temperature of 9th week (X_{209}). The weeks correspond to sowing, vegetative, flowering and podding stages of groundnut crop. The coefficient of determination varied from 64.18 to 75.88 % and the deviation in predicted values varied from 6.75 to 63.66 per cent (Table.10).

Among the different models developed under four approaches, 14 week crop period model could be preferred for forecasting groundnut yield, because of high R^2 (> 75%) value and less range of deviation of forecast yield from actual yields (< 7 %). Therefore, the following forecast model of groundnut yield of Rajkot district was considered appropriate.

$$\mathbf{Y = 3623.71 + 4.93\,T - 62.74^{*}\,X_{101} - 28.09^{**}\,X_{209} - 57.30^{*}\,X_{311} + 19.02^{**}\,X_{405} + 5.40^{**}X_{406} + 31.82^{**}\,X_{408} + 5.33^{**}\,X_{410} + 68.78^{**}\,X_{512} + 2.55^{**}\,X_{601} + 7.00^{**}\,X_{602}\;(R^2 = 75.88\%)}$$

CONCLUSION

The perusal of the results of Rajkot district indicated that the 14 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 (> 75%) and simulated forecast error was less than 7 per cent. This model could be utilized for pre-harvest forecast 4 weeks before expected harvesting period of groundnut crop.

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Table 1: Various physiological stages and meteorological standard week of groundnut crop.

Sr. No.	Stages	Crop duration (days)	Meteo. Week	Meteo. Period
1	Establishment (sowing and germination)	7 – 10	24-25	11th June to 24th June
2	Vegetative	10 – 20	26-27	25th June to 8th July
3	Flowering	40 – 45	28-30	9th July to 29 July
4	Podding	60 - 70	31-33	30th July to 19th Aug.
5	Maturity	100 - 105	34-38	20th Aug. to 23th Sep.
6	Harvesting	110-120	39-40	24th Sep. to 7th Oct.

Source: As per personal inquiry in Department of Agronomy, J.A.U., Junagadh.

Table 2: Variables included in the model week wise approach up to 18 weeks crop period

Meteo. Std. Week No.	Crop Week No.	Temperature		Relative humidity		Sun shine hour	Rain-fall
		Max	Min.	M	E		
		X_{1j}	X_{2j}	X_{3j}	X_{4j}	X_{5j}	X_6
24	01	X_{101}	X_{201}	X_{301}	X_{401}	X_{501}	X_6
25	02	X_{102}	X_{202}	X_{302}	X_{402}	X_{502}	
26	03	X_{103}	X_{203}	X_{303}	X_{403}	X_{503}	
27	04	X_{104}	X_{204}	X_{304}	X_{404}	X_{504}	
28	05	X_{105}	X_{205}	X_{305}	X_{405}	X_{505}	
29	06	X_{106}	X_{206}	X_{306}	X_{406}	X_{506}	
30	07	X_{107}	X_{207}	X_{307}	X_{407}	X_{507}	
31	08	X_{108}	X_{208}	X_{308}	X_{408}	X_{508}	
32	09	X_{109}	X_{209}	X_{309}	X_{409}	X_{509}	
33	10	X_{110}	X_{210}	X_{310}	X_{410}	X_{510}	
34	11	X_{111}	X_{211}	X_{311}	X_{411}	X_{511}	
35	12	X_{112}	X_{212}	X_{312}	X_{412}	X_{512}	
36	13	X_{113}	X_{213}	X_{313}	X_{413}	X_{513}	
37	14	X_{114}	X_{214}	X_{314}	X_{414}	X_{514}	
38	15	X_{115}	X_{215}	X_{315}	X_{415}	X_{515}	
39	16	X_{116}	X_{216}	X_{316}	X_{416}	X_{516}	
40	17	X_{117}	X_{217}	X_{317}	X_{417}	X_{517}	
41	18	X_{118}	X_{218}	X_{318}	X_{418}	X_{518}	
T= Time trend Y= Yield							

Table 3: Regression equations for 11 - week crop period of Rajkot district

Variables In model	Models for different years			
	Model-I (31 year)	Model-II (32 year)	Model-III (33 year)	Model-IV (34 year)
Constant	**-2104.17**	**-3416.86**	**-3190.67**	**-2849.45**
T	3.53**	11.15**	11.87**	9.08**
X_{101}	-27.08*	-6.56*	-15.17*	-37.26*
X_{309}	5.46*	3.84*	4.91*	10.67*
X_{404}	28.22**	26.92**	25.76**	23.96**
X_{406}	14.58**	19.12**	18.26**	15.98**
X_{410}	-6.13**	0.98**	2.17**	3.72**
X_{502}	61.14**	83.41**	75.00**	60.12**
X_{601}	11.13**	9.83**	10.42**	11.48**
X_{602}	22.30**	20.00**	18.95**	17.63**

S.E.	384.26	434.57	426.49	424.26
R^2 (%)	**72.97**	**68.94**	**68.86**	**68.34**

*Significant at 5 per cent level. ** Significant at 1 per cent level.

Table 4: Simulated forecast values for 11 - week crop period of Rajkot district (week wise approach)

Year	Observed yield (kg/ha)	Predicted values (kg/ha)			
		Model-I (31 year)	Model-II (32 year)	Model-III (33 year)	Model-IV (34 year)
2007-08	**2090**	1840 (11.94)	--	--	--
2008-09	**971**	603 (37.91)	748 (22.99)	--	--
2009-10	**273**	295 (8.38)	385 (41.35)	355 (30.31)	--
2010-11	**2027**	908 (55.19)	1129 (44.28)	1200 (40.78)	1215 (40.06)

Figures in ( ) are percent deviation from observed yield.

Table 5: Regression equations for 12 - week crop period of Rajkot district

Variables In model	Models for different years			
	Model-I (31 year)	Model-II (32 year)	Model-III (33 year)	Model-IV (34 year)
Constant	**-805.24**	**-573.04**	**-356.40**	**841.34**
T	12.10**	16.68**	15.99**	11.68**
X_{101}	-56.22*	-63.31*	-64.23*	-82.45*
X_{209}	-10.92**	-22.11**	-26.27**	-39.47**
X_{406}	13.96**	15.29**	15.13**	13.22**
X_{408}	19.10**	14.12**	14.13**	10.66**
X_{410}	7.99**	16.10**	15.47**	16.96**
X_{601}	19.17**	17.23**	17.01**	17.96**
X_{602}	8.62**	5.50**	5.62**	6.44**
S.E.	436.87	487.63	477.76	472.82
R^2 (%)	**63.39**	**59.12**	**59.22**	**59.03**

*Significant at 5 per cent level. ** Significant at 1 per cent level.

Table 6: Simulated forecast values for 12-week crop period of Rajkot district (week wise approach)

Year	Observed yield (kg/ha)	Predicted values (kg/ha)			
		Model-I (31 year)	Model-II (32 year)	Model-III (33 year)	Model-IV (34 year)
2007-08	**2090**	1729 (17.25)	--	--	--
2008-09	**971**	846 (12.91)	976 (0.46)	--	--
2009-10	**273**	281 (3.21)	347 (27.43)	333 (22.07)	--
2010-11	**2027**	2337 (15.30)	2355 (16.18)	2319 (14.45)	2228 (9.96)

Figures in ( ) are percent deviation from observed yield.

Table 7: Regression equations for 13 - week crop period of Rajkot district

Variables In model	Models for different years			
	Model-I (31 year)	Model-II (32 year)	Model-III (33 year)	Model-IV (34 year)
Constant	**1712.31**	**163.64**	**492.28**	**406.91**
T	4.55**	11.23**	10.17**	11.25**
X_{101}	-85.88*	-74.11*	-75.18*	-72.23*
X_{209}	-49.83**	-44.15**	-49.83**	-48.59**

X_{406}	16.19**	21.20**	20.80**	21.07**
X_{410}	16.75**	25.05**	24.03**	23.23**
X_{507}	54.09**	81.09**	80.50**	76.55**
X_{512}	-0.51**	4.52**	2.19**	5.22**
X_{601}	17.01**	14.60**	14.29**	14.02**
X_{602}	10.26**	7.05**	7.24**	7.14**
S.E.	481.28	501.32	491.05	481.70
R^2 (%)	**57.59**	**58.67**	**58.71**	**59.18**

*Significant at 5 per cent level. ** Significant at 1 per cent level.

Table 8: Simulated forecast values for 13 - week crop period of Rajkot district (week wise approach)

Year	Observed yield (kg/ha)	Predicted values (kg/ha)			
		Model-I (31 year)	Model-II (32 year)	Model-III (33 year)	Model-IV (34 year)
2007-08	**2090**	1700 (18.61)	--	--	--
2008-09	**971**	927 (4.56)	1119 (15.14)	--	--
2009-10	**273**	152 (44.09)	211 (22.68)	287 (5.26)	--
2010-11	**2027**	1946 (3.97)	2089 (3.06)	2040 (0.66)	2034 (0.35)

Figures in ( ) are percent deviation from observed yield.

Table 9: Regression equations for 14 - week crop period of Rajkot district

Variables In model	Models for different years			
	Model-I (31 year)	Model-II (32 year)	Model-III (33 year)	Model-IV (34 year)
Constant	**3623.71**	**2296.20**	**1787.37**	**3761.00**
T	4.93**	13.16**	14.50**	6.68**
X_{101}	-62.74*	-76.09*	-75.45*	-103.00*
X_{209}	-28.09**	-35.22**	-29.27**	-50.80**
X_{311}	-57.30*	-38.39*	-36.08*	-32.04*
X_{405}	19.02**	16.43**	16.02**	14.94**
X_{406}	5.40**	8.18**	8.73**	4.95**
X_{408}	31.82**	23.23**	23.10**	15.58**
X_{410}	5.33**	15.45**	16.33**	17.58**
X_{512}	68.78**	70.92**	73.84**	48.19**
X_{601}	2.55**	4.53**	5.39**	7.69**
X_{602}	7.00**	3.62**	3.48**	5.33**
S.E.	381.57	478.18	467.35	471.32
R^2 (%)	**75.88**	**65.81**	**65.85**	**64.18**

*Significant at 5 per cent level. ** Significant at 1 per cent level.

Table 10: Simulated forecast values for 14 - week crop period of Rajkot district (week wise approach)

Year	Observed yield (kg/ha)	Predicted values (kg/ha)			
		Model-I (31 year)	Model-II (32 year)	Model-III (33 year)	Model-IV (34 year)
2007-08	**2090**	1433 (31.38)	--	--	--
2008-09	**971**	353 (63.66)	800 (17.67)	--	--
2009-10	**273**	179 (34.15)	207 (23.87)	291 (6.75)	--
2010-11	**2027**	1623 (19.91)	1804 (10.95)	1871 (7.65)	1740 (14.14)

Figures in ( ) are percent deviation from observed yield.