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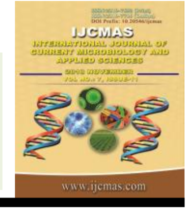

Original Research Article

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Forecasting Yield of Major Crops in Different District of Middle Gujarat and North Gujarat Using Statistical Techniques

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A B S T R A C T

Pre harvest forecast of agricultural production is essentially required for food security point of view. In this paper attempt has been made to develop model for forecasting the yield of kharif (Groundnut, paddy, maize) and rabi (wheat and mustard) crop of different district of middle Gujarat and north Gujarat using regression technique. The model were developed base on 30 years (1985 to 2015) district wise crop yield and weekly meteorological data and validated with 2 years (2010-11 & 2011-12) and forecast were issued for 2012-13. The result showed that for kharif crop the model developed could explain 40 to 90% variation in groundnut yield 47 to 93% variation in paddy yield 54 to 87% variation in maize yield in different district of middle and north Gujarat. For rabi crops (wheat and mustard) the models explained about 60 to 90% variation in the yield in different districts. The R^2 obtained were found to be significant at P=0.01. During validation period (2010 &11) the predicted yield deviations less than 10% of the reported yields were crop and districts. This revealed that the models can successfully be used for yield forecasting. The district wise yield forecast was issued for different crops for year 2012-13. The details of the findings are discussed in the paper.

Introduction

India has a comprehensive system for collection of Agricultural Statistics.

Most of the Indian States have an official agency (Revenue administration) which collects and compiles crop area and production estimates at the village level and transmits it for aggregation at higher levels (national/state/district). These estimates suffer from large time lag and non-sampling errors. Ministry of Agriculture required timely and accurate estimates for taking various policy decisions.

It was felt that crop forecasts should also take into account economic and weather variables which play a vital role in influencing farmer's decisions on sowing of different crops. These include both exogenous (weather) and endogenous variables (Prices, fertilizers, seeds, irrigation facilities etc.). Initially the models were developed to study crop weather relationship but later they were applied to forecast (Jain, 1980; Agrawal, 1986).

Yield forecast models were developed for wheat and rice using weather variables and agricultural inputs on agro-climatic zone basis by (Agrawal *et al.,* 2001). By coupling technology trend with weather variables, models were found to perform better Mallick *et al.,* 2007). The present study provides yield forecast models for major crops for different district of middle and north Gujarat using technique developed at IASRI, New Delhi (Agrawal *et al.,* 1980 & Jain *et al.,* 1980)

Materials and Methods

Data used

Twenty seven years (1985 to 2012) was collected for Directorate of Agriculture, Gandhinagar and corresponding weather data were collected from the agro-meteorological observatories situated in respective districts (Table 1). Crops and districts of middle and north Gujarat were selected based on terms of area and production of each crop districts for their significant contribution at state level. It may be seen that some station have little less no. of years of weather data. In Kharif season paddy, maize and groundnut were chosen while for rabi season wheat and mustard was chosen for yield prediction. In all the case data upto 2009 were used for development for model and two year (2010-11 and 2011-12) were used for validation purpose.

Techniques applied for development of district wise statistical models

Following the methodology suggested by Indian Agricultural Statistical Research Institute (IASRI), New Delhi (Agrawal *et al.,* 1980; Jain *et al.,* 1980).

The crop yield forecasting models for major growing districts were developed using stepwise regression analysis. Weather variables are used as independent variables which are related to crop responses such as yield and to account for the technological changes some function of time is used as independent variables. IASRI modified the model of Hendricks and Scholl (1943) by expressing the effects of changes in weather variables on yield as function of respective correlation coefficients between yield and weather variables (Table 2). This explains the relationship in a better way as it gives appropriate weightage to different periods. Under this assumption, the models were developed for studying the effects of weather variables on yield. These models are found to be better than the one suggested by Hendricks and Scholl in 1943 (Agrawal, *et al.,* 1986; Mehta *et al.,* 2000). The forecast model finally recommended is as follows

$$Y = A_0 + \sum_{i=1}^{p}\sum_{j=0}^{1} a_{ij}\ z_{ij} + \sum_{i \neq i'=1}^{p}\sum_{j=0}^{1} a_{ii'j}\ z_{ii'j} + cT + e$$

Where,

$Z_{ij} = \sum_{w=1}^{m} r_{iw}^{j}\ x_{iw}$ and $Z_{ii'j} = \sum_{w=1}^{m} r_{ii'w}^{j}\ x_{iw} x_{i'w}$

r_{iw} - is correlation coefficient of yield with i-th weather variable in w-th period

$r_{ii'w}$ - is correlation coefficient (adjusted for trend effect) of yield with product of i-th and i'-th weather variables in w-th period

m - is period of forecast

P - is number of weather variables used

e - is random error distributed as N(0, σ2)

The following eight weather variables were selected for development of models

Bright sunshine hour (BSS)

Maximum temperature (Tmax)
Minimum temperature (Tmin)
Morning relative humidity (RH1)
Afternoon relative humidity (RH2)
Morning vapour pressure (VP1)
Afternoon vapour pressure (VP2)
Rainfall (Rain)

For each weather variable, two weather indices were developed, one as simple accumulation of weather variable and the other one as weighted accumulation of weekly weather variable, weights being correlation coefficients of weather variable in respective weeks with yield (adjusted for trend effect, if present). Similarly, for interaction of weather variables, indices were generated using weekly products of weather variables taking two at a time. Stepwise regression technique was used to select the important weather indices. These weighted coefficients were finally regressed with the district yield to find out the final model. The final models were selected on the basis of highest R^2 and the value of significance of F test. Although for project work the models were separately developed for mid-season forecast at F1 stage (by 15th September) and final forecast at F2 stage (by 15th October) for kharif crops but here the models and results are presented for final and forecasts issued. Similarly for Rabi crops the models were developed using data upto to 20th February

Results and Discussion

Development of district wise yield forecasting models for kharif 2012 using data up to 15th October

The second (F_2) stage yield forecasting models were developed using the crop yield and weather data from 15th June to 15th October for *kharif* crops like paddy, groundnut and maize crops for the districts of Gujarat state (Table 3). The crop wise details are described as below.

Paddy

For Paddy crop for Anand the variables weighted Tmax (Z_{21}), Time, and weighted Tmax*rainfall (Z_{281}) found to be significant. Similarly the variables found significant for Baroda district were Time, weighted RH1 (Z_{41}), weighted Tmin*RH2 (Z_{251}) and for Panchmahal district the variables found significant were Time, weighted Tmax (Z_{21}), weighted Tmax*rainfall (Z_{31}) and weighted Tmin (Z_{31}). For Kheda district the variables that affected the yield significantly were Time, weighted RH2*rainfall (Z_{581}) and weighted Tmax*RH1 (Z_{241}). For Banaskantha district weighted Tmax*rainfall (Z_{281}), Time and weighted Tmin (Z_{31}) were found to be significantly responsible for yield prediction. Similarly for Dahod district the variables Time, weighted Tmax*rainfall (Z_{281}) and weighted Tmax (Z_{21}) and for Bhavnagar district the variables weighted Tmin*rainfall (Z_{381}) were found to be significant. Similar results were also found for pre-harvest forecast of sugarcane. (Krishna and Suresh. 2010)

Groundnut

For Groundnut crop for Anand and Kheda district the variable weighted Tmax*Tmin (Z_{231}) alone found to be significantly responsible for yield prediction. For Baroda district Time, weighted coefficient for Tmax*RH2 (Z_{251}), weighted coefficient for RH1 (Z_{41}) were found to be significant. For Panchmahal and Dahod district weighted Tmin*RH2 (Z_{351}) and weighted RH2 (Z_{51}) respectively contributed significantly for yield prediction. For Banaskantha district weighted Tmax (Z_{21}), Time, weighted coefficient for Tmax*RH1 (Z_{241}) found to be significant. For Bhavnagar district the variables Time, weighted coefficient for Tmax*Tmin (Z_{231}) and weighted RH1*rainfall (Z_{481}) were included in the model. Ramakrishna *et al.*,

(2003) have also developed forecast equations base on regression model, for total Indian food grain production using monsoon rainfall and soil index.

Maize

The maize yield forecasting models also performed well for the districts. For Anand districts the variables coefficient for Tmax*Tmin (Z_{231}), Time, weighted RH2*rainfall (Z_{581}), for Baroda district the variables weighted Tmin*RH2 (Z_{31}) and unweighted coefficient for RH1*RH2 (Z_{31}) were found to be significant.

The Variables weighted RH1 (Z_{31}) found to be significantly influencing the yield prediction for Panchmahal and Dahod district. Similarly the variables weighted Tmax*RH1 (Z_{31}), weighted RH2*rainfall (Z_{31}) for Kheda district, the variables Time, weighted Tmax*RH1 (Z_{31}) and weighted rainfall for Banaskantha district found to be significantly affecting the yield prediction. Similar study war carried out by Baweja, P.K. (2002).Predicted grain yield of maize on the basis of canopy temperature indices.

Development of district wise yield forecasting models for rabi 2012-13 using data up to 20th February

Wheat

The crop yield forecasting models were developed during the *rabi* season 2012-13 using the weather data up to 20th February for major growing district of crops viz., Wheat (Kheda, Anand, Bhavnagar, Panchmahal, Dahod, Banaskantha, Sabarkantha and Baroda), Mustard (Banaskantha and Sabarkantha) (Table 4).

Table.1 Data Used for the Analysis

Districts	Agro-met stations	Period available weather data	Crops selected	
			Kharif	Rabi
Anand	Anand	1985 – 2012	Paddy, maize & groundnut	Wheat
Kheda	Nawagam	1985 – 2012	Paddy, maize & groundnut	Wheat
Banaskantha	S K Nagar	1985 – 2012	Paddy, maize & groundnut	Wheat & mustard
Panchmahal	Godhra	1989 – 2012	Paddy, maize & groundnut	Wheat
Baroda	Baroda	1992 – 2012	Paddy, maize & groundnut	Wheat
Bhavnagar	Mahuva	1987 – 2012	Paddy & groundnut	Wheat
Dahod	Dahod	1989 – 2012	Paddy, maize & groundnut	Wheat
Sabarkantha	Khedbrahma	1985 – 2012	Paddy, maize & groundnut	Wheat & mustard

Table.2 Variables used in model development and their description

Symbols	Description	Symbols	Description
Z10	Unweighted coefficients for BSS	Z11	**Weighted coefficients for BSS**
Z20	Unweighted coefficients for Tmax	Z21	**Weighted coefficients for Tmax**
Z30	Unweighted coefficients for Tmin	Z31	**Weighted coefficients for Tmin**
Z40	Unweighted coefficients for morning hours humidity	Z41	**Weighted coefficients for morning hours humidity**
Z50	Unweighted coefficients for evening hours humidity	Z51	**Weighted coefficients for evening hours humidity**
Z60	Unweighted coefficients for Morning hours Vapour pressure	Z61	**Weighted coefficients for Morning hours Vapour pressure**
Z70	Unweighted coefficients for Evening hours Vapour pressure	Z71	**Weighted coefficients for Evening hours Vapour pressure**
Z80	Unweighted coefficients for Rainfall	Z81	**Weighted coefficients for Rainfall**
Z 120	Unweighted coefficients for BSS*Tmax	Z 121	**Weighted coefficients for BSS*Tmax**
Z 130	Unweighted coefficients for BSS*Tmin	Z 131	**Weighted coefficients for BSS*Tmin**
Z 140	Unweighted coefficients for BSS*morning hours humidity	Z 141	**Weighted coefficients for BSS*morning hours humidity**
Z 150	Unweighted coefficients for BSS* Evening hours Humidity	Z 151	**Weighted coefficients for BSS*morning hours humidity**
Z 160	Unweighted coefficients for BSS*Morning hours Vapour Pressure	Z 161	**Weighted coefficients for BSS*Morning hours Vapour Pressure**
Z 170	Unweighted coefficients for BSS*Evening hours Vapour Pressure	Z 171	**Weighted coefficients for BSS*Evening hours Vapour Pressure**
Z 230	Unweighted coefficients for Tmax*Tmin	Z 231	**Weighted coefficients for Tmax*Tmin**
Z240	Unweighted coefficients for Tmax* morning hours humidity	Z241	**Weighted coefficients for Tmax* morning hours humidity**
Z250	Unweighted coefficients for Tmax* Evening hours Humidity	Z251	**Weighted coefficients for Tmax* Evening hours Humidity**
Z260	Unweighted coefficients for Tmax*Morning hours Vapour Pressure	Z261	**Weighted coefficients for Tmax*Morning hours Vapour Pressure**
Z270	Unweighted coefficients for Tmax*Evening hours Vapour Pressure	Z271	**Weighted coefficients for Tmax*Evening hours Vapour Pressure**
Z280	Unweighted coefficients for Tmax*Rainfall	Z280	**Weighted coefficients for Tmax*Rainfall**
Z 340	Unweighted coefficients for Tmin*Morning hours Humidity	Z 341	**Weighted coefficients for Tmin* Morning hours Humidity**
Z 350	Unweighted coefficients for Tmin*Evening hours Humidity	Z 351	**Weighted coefficients for Tmin* Evening hours Humidity**
Z 360	Unweighted coefficients for Tmin*Morning hours Vapour Pressure	Z 361	**Weighted coefficients for Tmin*Morning hours Vapour Pressure**
Z 370	Unweighted coefficients for Tmin*Evening hours Vapour Pressure	Z371	**Weighted coefficients for Tmin*Evening hours Vapour Pressure**
Z 380	Unweighted coefficients for Tmin*Rainfall	Z381	**Weighted coefficients for Tmin*Rainfall**
Z 450	Unweighted coefficients for Morning hours Humidity *Evening hours Humidity	Z 451	**Weighted coefficients for Morning hours Humidity *Evening hours Humidity**
Z 460	Unweighted coefficients for Morning hours Humidity *Morning hours Vapour Pressure	Z461	**Weighted coefficients for Morning hours Humidity *Morning hours Vapour Pressure**
Z470	Unweighted coefficients for Morning hours Humidity *Evening hours Vapour Pressure	Z471	**Weighted coefficients for Morning hours Humidity *Evening hours Vapour Pressure**
Z480	Unweighted coefficients for Morning hours Humidity *Rainfall	Z481	**Weighted coefficients for Morning hours Humidity *Rainfall**
Z 560	Unweighted coefficients for Evening hours Humidity *Morning hours Vapour Pressure	Z 561	**Weighted coefficients for Evening hours Humidity *Morning hours Vapour Pressure**
Z 570	Unweighted coefficients for Evening hours Humidity *Evening hours Vapour Pressure	Z 571	**Weighted coefficients for Evening hours Humidity *Evening hours Vapour Pressure**
Z 580	Unweighted coefficients for Evening hours Humidity *Rainfall	Z 581	**Weighted coefficients for Evening hours Humidity *Rainfall**
Z670	**Unweighted coefficients for Morning hours Vapour Pressure* Evening hours Vapour Pressure**	**Z 671**	**Weighted coefficients for Morning hours Vapour Pressure*Evening hours Vapour Pressure**

Table.3 District wise crop yield forecasting model using data up to 15 October (F2)

Crop	District	Regression equation	R^2	Forecast yield (Kg/ha) for 2012
Groundnut	Anand	Y = 4520.03 + 3.47*Z231	0.53	1985
	Baroda	Y = -697.03 + 47.02*TIME + 0.19*Z251 + 6.77*Z41	0.93	1960
	Panchmahal	Y = 1479.39 + 0.42*Z351	0.40	1442
	Kheda	Y = 3258.66 + 3.16*Z231	0.59	1598
	Banaskantha	Y = 2347.30 + 63.26*Z21 + 18.04*TIME + 0.68*Z241	0.68	1548
	Dahod	Y = 1498.48 + 11.36*Z51	0.55	1564
	Bhavnagar	Y = 1063.11 + 29.63*TIME + 0.95*Z231 + 0.03*Z481	0.74	1272
Paddy	Anand	Y = 4268.57 + 37.88*Z21 + 32.63*TIME + 0.15*Z281	0.73	2453
	Baroda	Y = 2119.14 + 50.86*TIME + 8.85*Z41 + 0.17*Z351	0.96	1751
	Panchmahal	Y = 1107.62 + 61.56*TIME + 53.61*Z21 + 0.05*Z281 + 15.41*Z31	0.97	2159
	Kheda	Y = 315.59+ 37.42*TIME + 0.04*Z581 + 0.37*Z241	0.79	2231
	Banaskantha	Y = 112.59 + 0.05*Z281 - 10.39*TIME + 43.53*Z31	0.70	1136
	Dahod	Y = 2383.66 + 51.88*TIME + 0.10*Z281 + 36.33*Z21	0.84	1775
	Bhavnagar	Y = 1641.57 + 0.20*Z381	0.47	1651
Maize	Anand	Y = -166.71 + 1.98*Z231 + 38.16*TIME + 0.06*Z581	0.67	2507
	Baroda	Y = 1744.56 + 0.36*Z351 - 0.01*Z450	0.85	1673
	Panchmahal	Y = 723.74 + 24.43*Z41	0.61	1392
	Kheda	Y = -2352.12 + 0.47*Z241 + 0.04*Z581	0.54	1668
	Banaskantha	Y = 5724.22 + 55.87*TIME + 0.42*Z241 + 2.50*Z81	0.82	2394
	Dahod	Y = 1567.35 + 22.71*Z41	0.59	1447

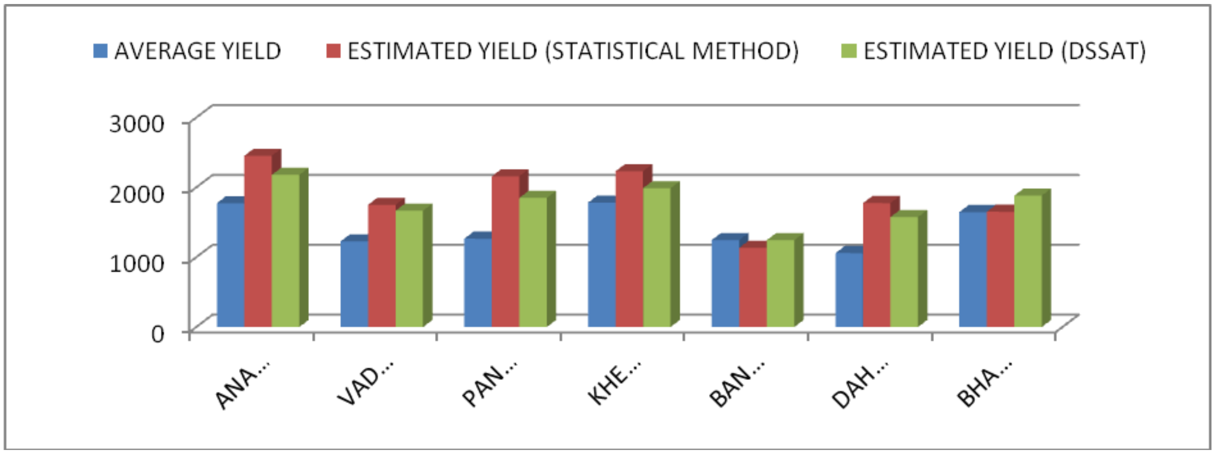
Table.4 Development of district wise yield forecasting for rabi 2012-13

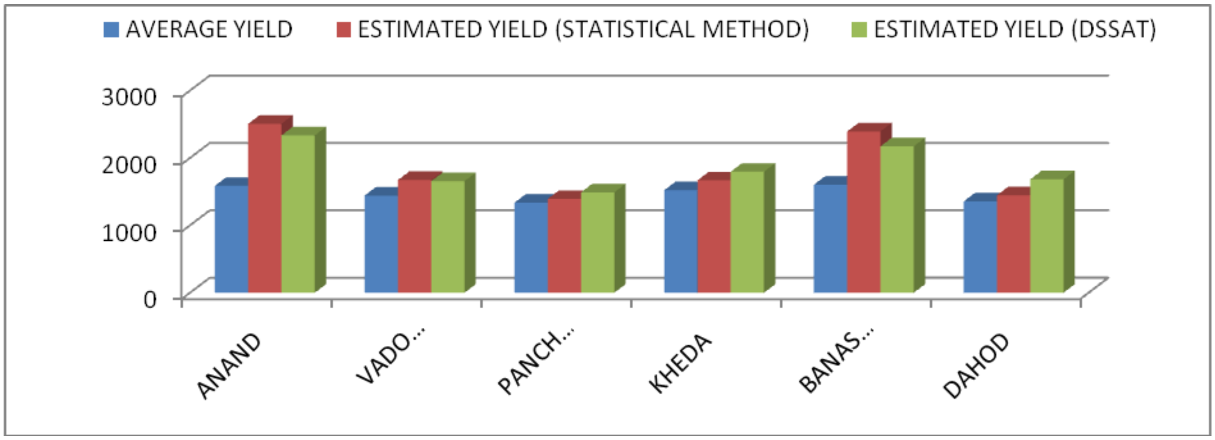
Crop	Districts	Regression equation	R^2	Forecasted yield (Kg/ha) for 2012-13
Wheat	Anand	Y = 1190.56 + 53.37*Time + 1.12*Z351	0.89	2841
	Baroda	Y = 6294.75 + 134.26*Z11 + 0.33*Z241 + 0.11*Z140	0.89	2602
	Panchmahal	Y = 1345.78 + 1.48*Z141 + 40.76*Z21 + 3.94*Z20 – 0.54*Z160	0.89	2020
	Kheda	Y = 1193.44 + 60.29*Time + 39.30*Z61 + 0.69*Z151 + 1.13*Z141	0.94	3052
	Banaskantha	Y = 3729.64 + 13.31*Z161 + 1.07*Z231	0.60	2641
	Dahod	Y = 3105.66 + 236.79*Z11 + 0.31*Z251 + 0.44*Z341	0.85	2054
	Bhavnagar	Y = -972.03 + 52.15*Time + 378.02*Z11 + 0.81*Z241	0.85	3016
	Sabarkantha	Y = 5707.92 + 38.36*Z21 + 3.10*Z171 + 0.54*Z141	0.73	2474
Mustard	Banaskantha	Y = 3581.70 + 0.95*Z141 + 85.66*Z21	0.67	1569
	Sabarkantha	Y = 1495.87 + 13.93*Time + 0.39*Z341 + 1.84*Z121	0.84	1430

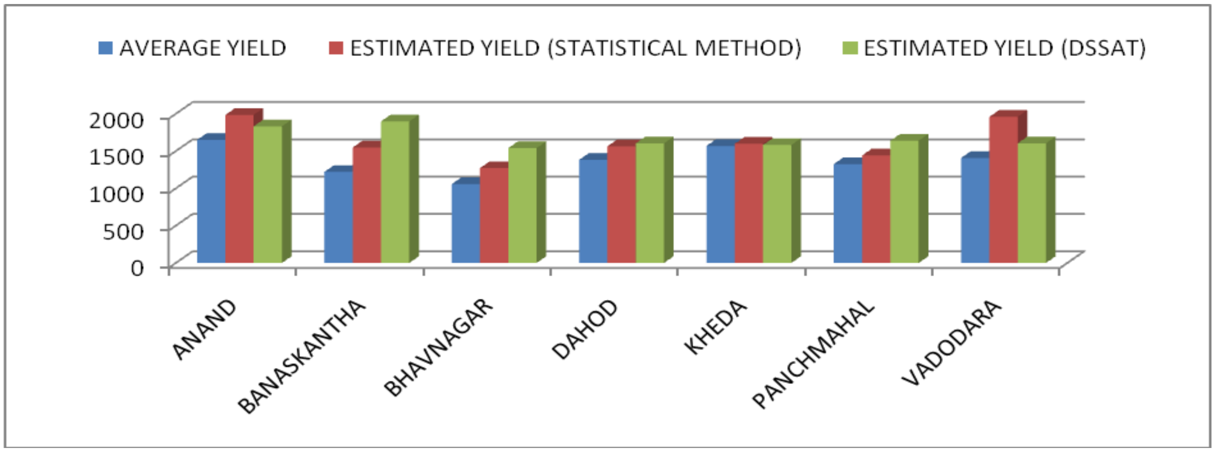
Table.5 Validation of statistical model in 2010 and 2011 for groundnut, paddy, maize and wheat different districts of Gujarat

Districts	Percent deviation of forecasts from observed yield (2010)				Percent deviation of forecasts from observed yield (2011)			
Anand	Groundnut	Maize	Paddy	Wheat	Groundnut	Maize	Paddy	wheat
Bananskantha	7.1	-7.9	2.1	3.2	-2.9	-5.0	0.3	-4.5
Bhavnagar	4.9	-	-9.0	-4.0	4.0	-	8.7	-1.9
Dahod	0.8	6.7	2.4	-5.5	4.1	-6.9	8.5	3.0
Kheda	8.0	8.0	-5.6	3.7	-8.2	7.2	-7.0	7.5
Panchmahal	6.7	4.2	-5.4	-6.3	0.4	8.4	2.4	-3.8
Vadodara	3.6	8.4	7.3	1.3	2.3	4.8	-1.6	6.7
	-5.5	3.4	4.8	2.2	-9.1	2.8	-6.9	3.8

Fig.1 Comparison with estimated yield by statistical method, crop weather simulation model (DSSAT) and average yield of rice, maize and groundnut for the different districts of Gujarat







The wheat yield prediction models for wheat growing districts were developed. There was quite strong relationship was found between actual yield and weather variables. For Anand district variables weighted BSS (Z_{511}), weighted Tmax*RH1 (Z_{241}) and unweighted BSS*RH1 (Z_{741}) were found to be significant. The variables found significant for Panchmahal district were weighted BSS*RH1 (Z_{141}), weighted and unweighted Tmax (Z_{20}) and weighted BSS*VP1 (Z_{160}). For Kheda district the variables Time, weighted VP1 (Z_{61}), weighted BSS*RH2 (Z_{151}), weighted BSS*RH1 (Z_{141}) and for Banaskantha district weighted BSS*VP1 (Z_{161}) and weighted Tmax*Tmin (Z_{231}) were found to be significantly responsible for yield prediction. The variables weighted BSS (Z_{11}), weighted Tmax*RH1 (Z_{241}) for Bhavnagar district and for Sabarkantha district the variables weighted Tmax (Z_{21}), weighted BSS*VP2 (Z_{171}) and weighted BSS*RH1 (Z_{141}) were included in the yield prediction model. Similar types of results were obtained by Agrwal and Aditya (2012) for yield prediction of wheat.

Mustard

For Mustard crop the variables found significant for Banaskantha district were weighted BSS*RH1 (Z_{141}) and weighted Tmax (Z_{21}). For Sabarkantha district the Time, weighted Tmin*RH1 (Z_{241}), weighted BSS*Tmax (Z_{121}) were found to be significant for yield prediction.

Crop yield prediction using crop growth simulation model (DSSAT v4.5)

The crop yield prediction was made using the DSSAT (v 4.5) crop growth simulation model (Table 4). The model was calibrated using the data (Crop and Weather) from 1990 to 2000 from all the stations and crops.

Data from 2001 to 2011 was used for validation of crop growth simulation model. The results presented in Figure 1 shows that there is no much difference forecasted crop yield by both the methods.

Validation of model

A comparison between the actual and predicted values of groundnut, paddy, maize and wheat yield for Anand, Baroda, Panchmahal, Kheda, Banaskantha, Dahod and Bhavnagar districts which were used in developing the forecast models, is presented in table 5. The results show that the percentage of deviations from the actual yield and forecasted yield is acceptable range raged between ±0.3 to 9.0 percent.

The results obtained by both the methods were nearly gave the same results. So from the results it can be concluded that both the methods are useful for the yield prediction purpose.

The DSSAT 4.5 crop growth simulation model gives the prediction considering the weather, soil and crop management data while statistical models are based on weather parameters only.

So if one is having all the data set (weather, soil and crop management data) it is better to go for crop growth simulation model otherwise statistical models also can serve the purpose if soil and crop management data are not available.

Using the forecast model, pre-harvest estimates of different crop yield for different districts of Gujarat could be computed successfully very much in advance before the actual harvest.

As the data used for developing this model is of high degree of accuracy, its reliability is also high. Further, this model will produce more accurate results depending on the accuracy of input data provided.

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