J. Agric. Res. Technol., 47 (1) : 043-049 (2022) https://doi.org/10.56228/JART.2022.47109

Pre Harvest Yield Forecasting Models for Western Maharashtra for Main Crops using Weather Indices

Krishna Kulkarni, S. B. Kharbade, V. A. Sthool and Shradha Bagade
Department of Agricultural Meteorology, College of Agriculture, Pune 411 005 (India)
Mahatma Phule Krishi Vidyapeeth, Rahuri - 413 722 (India)
Email : amfupune@gmail.com
(Received : 28.05.2021 Accepted : 22.06.2021)

Abstract

Forecasting models were developed using nineteen years (1998-2016) for cotton crop and twenty-seven years (1990-2016) of weather and yield data for sorghum and sugarcane crop. Models were validated for three years (2013-1015), two years (2014 and 2015) and three years (2013-1015) for cotton, sorghum and sugarcane crop respectively. R^2 values for all districts were above 0.6 which was good fit and per cent error of validation was near about ±10% for all districts in studied crops. Good agreements have been realized between actual and predicted yield with similar trends of deviation at preharvest stage. Hence these models can be used for forecasting sorghum yield in preharvest stage which is very useful to government authorities to plan the sorghum, cotton and sugarcane crop production more efficiently.

Key words : SPSS Statistical model, Pre harvest yield forecasting models, Weather indices, Cotton, validation, Sorghum, Sugarcane.

Total area under cotton during 2014-2015 was 41.92 LH (33.12%) and total production was 79.25 lakh gathis (19.81%) (ASDM, 2015) only, as compared to world and country it was very low so it has great scope to increase it by proper planning of yield by statistical means. Production of cotton can be increased by adapting new technologies and studying different parameters influencing yield. Districts selected for study in cotton crop were Dhule and Jalgaon in which cotton is mainly taken as rainfed and relation of all weather parameters with yield really noticeable. Sorghum (Sorghum bicolor (L.) Moench) in India called as jowar, is the fifth most important world cereal, following wheat, rice and maize. It is a staple food in the drier parts of Tropical Africa, India and China. It stands stress conditions and to some extent water logging. India contributes about 16% of the world's sorghum production. Sorghum grain yields in India have average 1170 kg ha^{-1} during Kharif season and 880 kg ha^{-1} during rabi season in 2014. Out of which 65% yield was contributed by Maharashtra for *rabi* season. Out of total area under rabi sorghum in India, Maharashtra contribute 58% area in 2014 (ASDM 2015). Sugarcane is the important cash crop of Maharashtra. Agriculture economy of Maharashtra is mainly depending on sugarcane crop. Total area under sugarcane crop in the country was 50.321 lakh hector (L.H.) during 2014-2015. Out of which 21% area i.e. 10.55 L.H. was in Maharashtra. Out of the total production of sugarcane 3565.60 Lakh Tons (LT) in India, 26% (930.41LT) was in Maharashtra. Total productivity of Maharashtra was (88T Ha^{-1}) which is more than national productivity (70T Ha^{-1}) (Krushidarshani 2016). Western Maharashtra contributes more area of cultivation as compared to other parts of Maharashtra under sugarcane crop. Pune, Ahmednagr, Solapur, Satara, Sangli, Kolhapur and Nashik districts from Western Maharashtra were selected for study. Weather is one of the crucial parameters affecting yield of all the crops. Several studies have indicated that adverse weather condition during the cropping season results in reduction of crop production of crops (Aggarwal *et al.*,1980, Agrawal *et al.*, 1983 and Agrawal *et al.* 1986). Crop acreage estimation and crop yield forecasting are two components, which are crucial for proper planning and policy making in the agriculture sector of the country. Models based on weather parameters can provide reliable forecast of crop yield in advance of the harvest and also forewarning of pest and diseases attack so that suitable plant protection measures could be taken up timely to protect the crop. (Agrawal and Mehta 2007). Therefore, cotton, sorghum and sugarcane models based on weather indices developed under FASAL (Forecasting Agriculture output Using Space, Agrometeorology and Land based observations) project at Ministry of Agriculture, Govt. of India in collaboration with India Meteorological Department (IMD). The present study was under taken to investigate the feasibility of estimating productivity of above crops based on weather variables using past weather and yield records of different districts of Maharashtra.

Materials and Methods

Weather data on daily basis at all districts were collected from research stations located at particular district and yield data were collected from Agriculture and Statistics Department, Govt. of Maharashtra. Two districts Dhule and Jalgaon which contribute more in total yield of cotton in Maharashtra were selected for the study. Weather data was used for cotton in Standard Meteorological Week wise (SMW), starting from 22^{nd} to 47^{th} SMW of each year i.e. the period from planting to pre-harvesting stage of cotton crop. Sorghum crop yield data for the period of 27 years (1990-2016) were used to develop yield forecasting models. Districts which contribute more in total yield of sorghum in Maharashtra were selected viz. Sangli, Solapur, Satara, Pune, Jalgaon and Ahmednagar. Weather data was used in Standard Meteorological Week wise (SMW), starting from 40^{th} to 2^{nd} SMW of each year i.e. the period from planting to preharvesting stage of sorghum crop. Sugarcane crop yield data for the period of 27 years(1990-2016) were used to develop yield forecasting models. Seven districts (Pune, Ahemednagr, Solapur, Satara, Sangli, Kolhapur and Nashik) which contribute more in total yield of sugarcane in Maharashtra were selected.Standard Meteorological Week wise (SMW) weather data was used starting from 6th to 47th SMW of each year. Variables used in the study were weekly rainfall (mm), maximum and minimum temperature (°C), RH I and RH II (%) for selecting the best regression equation. Among number of independent variables, stepwise regression procedure was adopted. Statistical Package for Social Science (SPSS) Computer Software was used for the analysis of data with probability level of 5% to enter and 1% to remove the variables. A regression model was fitted considering the entered variables obtained from individual stepwise regression analysis to predict the yield of cotton for the subsequent year. The multiple linear stepwise regression analysis has been developed on the basis of examination of coefficient of determination (R2), standard error (SE) of estimates values resulted from different weather parameters. The best agrometeorological yield model for each district developed as per methodology given by Ghosh *et al*., (2014). Weighted and unweighted weather index were used in analysis follow up. Yield forecast models for all districts which produce cotton, sorghum and sugarcane have been developed and their performances have been validated against the observed yield during 2013-2015.

Firstly, the relationship between yield and time was developed to find out whether the yield is sensitive to technological trends for the period under consideration or not. The yield data for districts is sensitive to the introduction of new varieties, irrigation facilities, fertilizer applications and rainfall distribution in that year. Simple weekly average and the weighted weekly average of the weather parameters were generated during the entire crop period. The weight was the value of correlation of the yield with respective weather variable for a particular week. To test interdependencies of various weather variables on the yield, the sum of the weather variables and sum product of the weighted weather variable were calculated for each year and this formed the data series for developing the regression equation. A total of 30 indices and time were taken as independent variable. The regression equation is developed using forward stepwise regression method between these 31 independent variables and dependent variable (yield). Year wise data of selected main crop was mentioned in Table 7.

Results and Discussion

Cotton crop (*Kharif*) : Using (SPSS) statistical model forecast was generated and validated for the years 2013, 2014 and 2015 and the deviations were found to be in the acceptable limits. Using the same equations, the forecast for 2016 has been issued. Forecasted yield and equations of models were given in Table 1. Coefficient of determination (R^2) has been significant at 5% probability level for cotton in two districts of Maharashtra. The forecasting models were able to explain inter annual variation in the cotton production to the extent of 87% for Dhule and 90% for Jalgaon. Table1 indicates the results of the forecast yield which are satisfactory and the performance of the yield forecasting is acceptable. The best agrometeorological indices to incorporate in the agrometeorolgical yield for cotton crop was selected like temperatures, relative humidity and rainfall. Out of which more influences the yield in cotton crop can be noted by equation as Rain*RHII (Z351), RHI (Z41) for Dhule districtand Rain*RH I (Z341),Tmax (Z10) for Jalgaon district.

The validation of models for cotton for 2013, 2014 and 2015 are shown in Table 2. Results revealed that in Dhule during 2013 (-5.1%) yield was over estimated in 2014 (1.6%) and 2015 (5.4%) yield was under estimated. For Jalgaon district during 2013 (4.6%) yield was under estimated and during 2014 (-9.3%) and 2015 (-9.2%) it was overestimated. A model has less than ±10% error in cotton yield prediction for districts during all 3 years of validation. This has indicated that the models can be used for prediction of cotton yield in the above districts.

Table 1. Yield forecast models of cotton for Dhule and Jalgaon districts

District	Equation	Forecasted yield (kg ha^{-1})	R^2 (%)	F
Dhule	Y= -207+0.006*Z341+3.42*Z41	215	.87	44.22
Jalgaon	Y= 1861.27+0.007*Z341-1.84*Z10	349	.90	59.21

Table 2. Validation of models for forecasting of cotton yield of Dhule and Jalgaon

Years Districts	2013			2014			2015		
	Actual (Kg ha^{-1})	Predicted (Kg ha^{-1})	Error %	Actual (Kg ha^{-1})	Predicted (Kg ha^{-1})	Error %	Actual (Kg ha^{-1})	Predicted (Kg ha^{-1})	Error %
Dhule	425.0	446.7	-5.1	329.0	323.8	1.6	268.0	253.6	5.4
Jalgaon	458.0	437.9	4.6	329.0	362.9	-9.3	268.0	295.3	-9.2

Sorghum (*rabi*) : Using statistical model (SPSS) forecast was generated and validated for the years 2014-2015 and the deviations were found to be in the acceptable limits. Using the same equations, the forecast for 2016 has been issued. Forecasted yield and equations of modelsfor sorghum were given in Table 1. Coefficient of determination (R^2) has been significant at 5 % probability level for sorghum in two districts of Maharashtra. The forecasting models were able to explain inter annual variation in the sorghum production to the extent of 84% for Sangli, 68% for Solapur, 64% for Satara, 72%f or Pune, 87% for Jalgaon and 90% for Ahmednagar. Table 1 indicates the results of the forecast yield are satisfactory and the performance of the yield forecasting is acceptable. The best agrometeorological indices to incorporate in the agrometeorolgical yield which for sorghum crop was selected like temperatures, relative humidity and rainfall. Out of which more influences the yield in sorghum crop can be noted by equation as Tmin*RHII (Z251), Tmax*Tmin (Z121) and Tmax*Rain (Z131) for Sangalidistrict;Tmax (Z11), Tmin*RHI (Z241) for Solapur; Tmax*Tmin (Z121), Tmin*RHII (Z251/Z250) for Satara district; Tmax* Tmin (Z121) Tmax* RHI (Z141) for Pune district; Time, Tmax*Tmin (Z121)and RHI*RHII (Z451) for Jalgaondistrict; Tmin*RHII (Z251),Tmax (Z11), Time and Tmax (Z31) for Ahmednagar district.

The validation of models for sorghum for year 2014 and 2015 are shown in table 2. Results revealed that in Sangali 2014 (10.5%) yield found under estimated 2015 (-17.6%) yield was over estimated. For Solapur district in 2014

Table 3. Yield forecast models of sorghum for given districts

District	Equation	Forecast yield kg ha^{-1}	R^2	F	Std. Error
Sangli	Y= 309.46+0.32*Z251+1.26*Z121+ 0.04*Z131	893	0.84	35.6	67.5
Solapur	Y= 1730.57+21.66*Z11+0.17*Z241	470	0.68	22.9	49.1
Satara	Y= 829.76+1.70*Z121+0.32*Z251+0.03*Z250	818	0.64	11.8	96.85
Pune	Y=-713.25+2.10*Z121+0.103*Z141	514	0.72	27.7	65.4
Jalgaon	Y=1531.68+23.29*Time+0.95*Z121+0.06*Z451	1720	0.87	43.3	93.5
Ahmednagar	Y= 3790.43+0.27*Z251+29.6*Z11+ 14.8*Time-1.79*Z31	594	0.90	24.9	63.8

Table 4. Validation of models for forecasting of sorghum yield of given districts

District	Sorghum Yield					
	2014			2015		
	Actual yield (kg ha^{-1})	Forecasted yield (kg ha^{-1})	% Error	Actual yield (kg ha^{-1})	Forecasted yield (kg ha^{-1})	% Error
Sangli	739	736.3	10.5	413	564	-17.6
Solapur	615	549	10.7	375	387	-3.1
Satara	863	871	-0.9	790	839	-6.1
Pune	772	736	4.6	448	564	-25.8
Jalgaon	2005	1799	10.2	1514	1671	-10.3
Ahmednagar	637	664	-4.2	328	396	-20.7

Table 5. Yield forecast models of sugarcane for different districts of western Maharashtra

District	Equation	Forecast yield kg ha^{-1}	R^2	F
Solapur	Y= 44740.5+0.88*Z451+0.99*Z351+1101.62*Z21	91596	0.73	20.8
Satara	Y= 320648.4+117.8*Z11+1.019*Z351+5.69*Z241	86891	0.84	34.8
Ahmednagar	Y= 377291.6+2551.32*Z11	79071	0.65	37.0
Kolhapur	Y= 136393.2+1747.22*Z11+4.52*Z141	70164	0.71	22.5
Nashik	Y=71866.8+1.264*Z351+5.89*Z241+2.32*Z120- 446.92*Time	67540	0.97	92.2
Pune	Y= 338117.9+2168.5*Z11	82363	0.61	34.3
Sangali	Y=103386.4+16.45*Z121+4.03*Z251+8.76*Z30+3.42*Z141	99758	0.94	61.8

(10.7%) yield was underestimated and 2015 (-3.1%) it was overestimated. For Satara district in 2014 (-0.9%) and 2015 (-6.1%) it was overestimated. For Pune district in 2014 (4.6%) yield was underestimated and 2015 (-25.8%) it was overestimated. For Jalgaon district in 2014 (10.2%) yield was underestimated and 2015 (-10.3%) it was overestimated. For Ahmednagar district in 2014 (-4.2%) and in 2015 (-20.7%) it was overestimated. A model has less than ±10% error in sorghum yield prediction for all districts (exception for 3 times only) during years of validation.This has indicates that the models can be used for prediction of sorghum yield in the above districts.

Sugarcane crop (*Kharif*) : Using statistical model (SPSS), forecast was generated and validated for the years 2013 - 2015 and the deviations were found to be in the acceptable limits. Using the same equations the forecast for 2016 has been issued.Forecasted yield and equations of models are given in Table 1. Coefficient of determination (R^2) has been significant at 5 % probability level for sugarcane in all seven districts of Western Maharashtra. R^2 values ranged between 61% (Pune) to 97% (Nashik). The forecasting models were able to explain inter annual variation in the sugarcane production to extent at 73%, 84%, 65%, 71%, 97%, 61% and 94% for Solapur, Satara, Ahmednagar, Kolhapur, Nashik, Pune and

Table 6. Validation of model for forecasting of sugarcane yield for different districts of Western Maharashtra

Year	Actual yield (kg ha^{-1})	Forecasted yield (kg ha^{-1})	% Error
Solapur			
2013	87000	85354.83	1.9
2014	100497	90062.76	10.3
2015	109644	97968.48	10.6
Satara			
2013	101000	106347	9.4
2014	102000	91128	11.9
2015	83258	95508	-11.8
Ahmednagar			
2013	68000	69005	-1.4
2014	59000	63597	-7.2
2015	66071	75070	-11.9
Kolhapur			
2013	98000	97829.64	0.1
2014	96000.0	95433.01	0.5
2015	130977	119947	8.4
Nashik			
2013	70000	69231	1.1
2014	70000	67524	3.6
2015	68312	70376	-2.9
Pune			
2013	93000	101659	-8.5
2014	80000	84076	-4.8
2015	112854	102059	9.5
Sangali			
2013	100000	100680	-0.6
2014	105000	94050	11.6
2015	86485	92052	-6.0

Sangali districts respectively. The results of the forecast yield are satisfactory and the performance of the yield forecasting is acceptable. The best agrometeorological indices to incorporate in the agrometeorolgical yield for sugarcane crop were selected like temperatures, relative humidity and rainfall. Out of which more influences the yield in sugarcane crop can be noted by equation as RHI*RHII (Z451), Rain*RHII (Z351) and Tmin (Z21) for Solapur district; Tmax (Z11), Rain*RHII (Z351) and Tmin*RHI (Z241) for Satara District; Tmax (Z11) for Ahmednagar and Pune districts; Tmax (Z11) and Tmax* RHI (Z141).for Kolhapur district ;Tmax *Tmin(Z121), Tmin*RHII (Z251), Rain(Z30) and Tmax* RHI (Z141) for Sangali district. Tmax , Relative humidity RHI and RHII, and rainfall separate and in combination plays very important role in sugarcane yield. Similar results were reported by Tripathi *et al.* (2012) who forecasted yield of sugarcane in preharvest stage for Uttar pradesh.

The validation of models for sugarcane for year 2013, 2014 and 2015 are shown in Table 2. Results revealed that in Solapur 2013 (1.9%),

Table 7. Crop wise yield data for different district in western Maharashtra from 1090-2016

Year	Cotton yield ($Kg\ ha^{-1}$)		Sorghum yield ($Kg\ ha^{-1}$)						Sugarcane yield ($Kg\ ha^{-1}$)						
	Dhu-le	Jal-gaon	Jal-gaon	San-gli	Sola-pur	Sat-ara	Pune	Ahm-edna-gar	Solapur	Satara	Ahmed-nagar	Kolh-apur	Nas-hik	Pune	Sangali
1990	-	-	1200	739	485	875	539	539	85332.0	87211	90211		-	89219	-
1991	-	-	1220	449	534	838	495	495	69480.0	82508	81240	93300	-	88930	-
1992	-	-	1051	418	313	721	360	360	68400.0	83340	81310	62000	-	81110	-
1993	-	-	1324	448	425	588	468	468	80000.0	88000	80000	85000	-	87000	-
1994	-	-	1259	607	577	764	609	609	85150.0	92300	90460	89180	-	89980	97090
1995	-	-	1208	313	327	699	372	372	85900.0	95900	83590	80620	-	90630	90280
1996	-	-	1006	620	650	714	419	419	90101.0	91882	80881	77518	-	84804	97092
1997	-	-	1158	513	518	726	467	467	79985.0	109317	87015	77239	-	95910	87382
1998	186	224	1155	645	558	785	532	532	88000.0	88000	107000	101000	90000	88000	98000
1999	116	239	1224	560	467	1018	536	536	100000.0	94000	93000	108000	83001	90000	106000
2000	85	116	1302	801	506	916	710	710	94000.0	92000	83000	96000	91000	77000	91000
2001	124	213	1004	530	448	510	416	416	85441.5	75811	74622	99608	78000	69160	94619
2002	92	207	1310	647	440	642	483	483	88000.0	72000	71000	89000	70001	67000	93000
2003	231	228	1584	376	335	434	347	347	69596.0	58261	33838	79644	56001	47654	67288
2004	209	265	1489	221	447	619	243	243	83755.3	72330	61919	83908	55001	58929	80832
2005	174	261	1588	531	441	861	532	532	93607.8	82877	64647	81424	51000	77655	88787
2006	253	325	1430	486	511	719	493	493	87884.9	85123	65872	93127	85001	65645	83683
2007	373	388	1464	588	481	804	512	512	97482.7	79274	66446	101230	69001	78260	84467
2008	112	305	1868	651	569	1027	538	538	97345.8	84718	65368	90922	69001	71804	83929
2009	260	282	1403	583	591	795	642	642	95315.2	92568	70353	85755	72000	83849	89446
2010	440	510	1640	600	539	897	738	738	88000.0	85000	78000	100000	77000	75000	89000
2011	265	252	1252	980	565	900	565	565	85000.0	81000	75000	95000	70000	88000	95000
2012	248	261	1895	500	499	577	546	546	81000.0	110000	93000	88000	70000	90000	102000
2013	425	458	2297	670	460	867	707	591	87000	101000	68000	98000	70000	93000	100000
2014	329	329	2005	739	615	863	772	637	100497	102000	59000	96000.0	70000	80000	105000
2015	268	268	1514	413	375	790	448	328	109644	83258	66071	130977	68312	112854	86485

2014 (10.3%) and 2015 (10.6%) in all validated years yield were under estimated. For Satara district 2013 (9.4%) and 2014 (11.9%) were underestimated while 2015(-11.8%) it was overestimated.For Ahmednagar all validated years show over estimated yield 2013 (-1.4%), 2014(-7.2%) and 2015(-11.9%). For Kolhapur district in all validated years yield were underestimated 2013(0.1%), 2014 (0.5%) and 2015(8.4%). For Sangali district 2013 (-0.6%) and 2015 (-6.0%) were overestimated while 2014 (11.6%) it was underestimated. A model has less than ±10 - 11% error in sugarcane yield prediction for all districts during all 3 years of validation. This has indicates that the models can be used for prediction of sugarcane yield in the above districts.

Conclusions

Yield forecast models for Major district were developed through statistical model. R^2 values for all districts were above 0.6 which was good fit and per cent error of validation was ±10% for all districts. Therefore, it could be used for yield forecasting satisfactorily for cotton, sorghum and sugarcane yield in Maharashtra. The results revealed that agrometeorological yield models explained the yield variability due to variations in temperatures and relative humidity during the different stages.Further separate Tmax with combination of RHI, RHII and rainfall have formed most important agrometeorological indices. This can be useful in forecasting of crops yield in advance in western Maharashtra.

Ackwledgement

We acknowledge the India Meteorological Department, Ministry of Earth Sciences for the financial support through FASAL Project.

References

Agarwal, R., Jain, R. C., Jha, M. P. and Singh, D. 1980. Forecasting of rice yield using climatic variables. Ind. J. Agri. Sci., 50(9): 680-684.

Agrawal, R., Jain, R. C. and Jha, M. P. 1983. Joint effects of weather variables on rice yield. Mausam, 34(2): 189-194.

Agrawal, R., Jain, R. C., and Jha, M. P. 1986. Models for studying rice crop-weather relationship., Mausam, 37(1):67-70.

Agrawal, R. and Mehta S. C. 2007. Weather based forecasting of crop yield, pest and diseases-IASRI models J. Ind. Soc. Agril. Statist. 61(2): 255-263.

ASDM. 2015. Agricultural Statistic Department of Maharashtra Report 2014-2015.

Ghosh K., Balsubramanyan, R., Bandopadhyay, S., Chatopadhyay, N., Singh, K. K. and Rathod L. S. 2014. Development of Crop Yield Forecast models under FASAL- a case study of kharif rice in West Bengal. J. Agrometeorol., 16(1): 1-8.

Krushidarshani. 2016. Mahatma Phule Krishi Vidypeeth, Rahuri. Ext. publication No. 2000. pp. 98-108.

Tripathi, M. K., Mehara B., Chatopadhyay, N. and Singh, K. K. 2012. Yield prediction of sugarcane and paddy for districts of Uttar Pradesh. J. Agrometeoro., 14(2): 173-175.