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Pre harvest yield forecasting models of sugarcane using weather indices in western Maharashtra

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Abstract
Forecasting models were developed using thirty one years (1990-2021) of weather and yield data of sugarcane crop. Models were validated for three years (2018-2020). Good agreements have been realized between actual and predicted yield with similar trends of deviation at prevest stage. Deviation of predicted yield was ± 10 - 11% in all studies district and R^2 values were 0.74, 0.65, 0.75, 0.88, 0.70, 0.90 and 0.84 for Solapur, Satara, Ahmednagar, Kolhapur, Nashik, Pune and Sangali districts respectively. Hence, these models can be used for forecasting sugarcane yield in preharvest stage which is very useful to government authorities to plan the sugarcane production more efficiently.

Keywords: Harvest, forecasting, sugarcane, weather, western, Maharashtra

Introduction
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 54.55 lakh hector (L.H.) during 2020-2021. Out of which 23% area i.e. 12.32 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 (90T/H) which is more than national productivity (76T/H) (DA&FW, 2021). 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) [1, 2, 3]. 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) [4]. Therefore, sugarcane models based on weather indices developed under FASAL (Forecasting Agriculture Output Using Space, Agrometeorology and Land based observations) project at Ministry of Agriculture, Government of India in collaboration with India Meteorological Department (IMD). The present study was under taken to investigate the feasibility of estimating productivity of sugarcane crop based on weather variables using past weather and yield records of different districts of Maharashtra.

Material and Methods
Sugarcane crop yield data for the period of 31 years (1990-2021) were used to develop yield forecasting models. Weather data on daily basis at different districts collected from different research stations located at particular district and yield data collected from Agriculture and Statistics Department, Government of Maharashtra. 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 42nd SMW of each year i.e. the period from planting to preharvesting stage of sugarcane crop. Variables used in the study were weekly rainfall (mm), maximum and minimum temperature (^{0}c), RH_1 and RH_2 (%) 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 0.05 to enter and 0.01 to remove the variables. A regression models was fitted considering the entered variables obtained from individual stepwise regression analysis to predict the yield of sugarcane for the subsequent year. The multiple linear stepwise regression analysis has been developed on the basis of examination of coefficient of determination (R^2), standard error (SE) of estimates values resulted from different weather parameters. The best agrometeorological yield model for each district as per methodology given by Ghosh *et al*. (2014) [5]. Weighted and unweight weather index were used in analysis follow up. Yield forecast models for all seven districts which produce sugarcane have been developed and their performance have been validated against the observed yield during 2018-2020. The relationship between yield and time was developed to find out whether the yield is sensitive to technological trends for the period under consideration. 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 variables. The regression equation is developed using forward stepwise regression method between these 31 independent variables and dependent variable (yield).

Results and Discussion

Using statistical model (SPSS), forecast was generated and validated for the years 2018 - 2020 and the deviations were found to be in the acceptable limits. Using the same equations the forecast for 2021 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. The R^2 values ranged between 65% (Satara) to 90% (Pune). The forecasting models were able to explain inter annual variation in the sugarcane production to extent at 74%, 65%, 67%, 88%, 70%, 90% and 84% for Solapur, Satara, Ahmednagar, Kolhapur, Nashik, Pune and 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 temperature, relative humidity and rainfall. Out of which more influences the yield in sugarcane crop can be noted by equation as RH_1*RH_2 (Z451), Rain*RH_2 (Z351) and Tmin (Z21) for Solapur district; Tmax (Z11), Rain*RH_2 (Z351) and Tmin*RH_1 (Z241) for Satara District; Tmax (Z11) for Ahmednagar and Pune districts; Tmax (Z11) and Tmax* RH_1(Z141).for Kolhapur district; Tmax *Tmin (Z121), Tmin*RH_2 (Z251), Rain (Z30) and Tmax* RH_1 (Z141) for Sangali district. Tmax, Relative humidity RH_1 and RH_2, and rainfall separate and in combination plays very important role in sugarcane yield. Similar results were reported by tripathi *et al*. (2017) [6] who forecasted yield of sugarcane in preharvest stage for Uttar pradesh. The validation of models for sugarcane for year 2018, 2019 and 2020 are shown in table 2. Results revealed that in Solapur 2018 (3.77%), 2019 (0.04%) and 2020 (3.4%) in all validated years yield were under estimated. For Satara district 2018 (5.43%) and 2019 (3.96%) were underestimated while 2020(-10.5%) it was overestimated. For Ahmednagar all validated years show over estimated yield 2018(3.06%), 2019(-8.1%) and 2020(-2.8%). For Kolhapur district in all validated years yield were overestimated 2018(2.53%), 2019 (-15.4%) and 2020(-7.84%). For Nashik district 2018 (7.89%) and 2019 (6.35%) were underestimated while 2020(6.49%). For Pune district 2018 (-8.5%) and 2019 (2.26%) were overestimated while 2020(1%) it was underestimated. For Sangali district 2018 (1.07%) 2019 (0.50%) and 2020 (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 indicates that the models can be used for prediction of sugarcane yield in the above districts. The results revealed that agrometeorological yield models explained the yield variability due to variations in temperatures and relative humidity during the different stages.

Table 1: Yield forecast models of sugarcane for different districts of western Maharashtra

SN	District	Equation	Forecast Yield mt/ha	R^2	F
1	Solapur	Y=51.17-0.001*Z130+0.679*Time-0.012*Z241	91.14	0.74	10.26
2	Satara	Y=218.726+0.001*Z451-0.003*Z240	93.98	0.65	9.67
3	Ahmednagar	Y=218.726+0.001*Z451-0.003*Z240	93.98	0.75	9.67
4	Kolhapur	Y=108.453+0.940*Time-0.010+0.006*Z141	103.83	0.88	7.02
5	Nashik	Y=130.537+0.00*Z350+0.251*Z41	76.39	0.70	8.81
6	Pune	Y=101.806+0.001*Z341+0.031*Z121+0.665*Z11-0.001*Z140	107.2	0.90	26.35
7	Sangli	Y=151.196+0.084*Z41	95.94	0.84	5.77

Table 2: Validation of model for forecasting of sugarcane yield for different districts of western Maharashtra

S.N.	Year	Actual Yield (Ton/ha)	Forecasted yield (Ton/ha)	% Error	S.N.	Year	Actual Yield (Ton/ha)	Forecasted yield (Ton/ha)	% Error
1	Solapur				5	Nashik			
	2018	91	87	3.77		2018	80	74.14	7.89
	2019	83	79	0.04		2019	75	70.52	6.35
	2020	91	88	3.40		2020	82	77	6.49
2	Satara				6	Pune			
	2018	97	92	5.43		2018	103	112	-8.24
	2019	91	87	3.96		2019	108	105	2.26

	2020	92	102	-10.5		2020	101	100	1
3	**Ahmednagar**				**7**	**Sangali**			
	2018	95	98	3.06		2018	103	98	1.07
	2019	71	77	-8.1		2019	100	99	0.50
	2020	95	97	-2.8		2020	120	113	6
4.	**Kolhapur**								
	2018	81	79	2.53					
	2019	82	97	-15.4					
	2020	94	102	-7.84					

Conclusions

Yield forecast models for western Maharashtra were developed through statistical model. Three years 2018, 2019 and 2020 were taken for validation. R^2 values for all districts were above 0.6 which was good fit and percent error of validation was ±10 - 11% for all districts. Therefore, it could be used for yield forecasting satisfactorily for sugarcane yield in western Maharashtra. Further Tmax, Tmin with combination of RHI, RHII and rainfall have formed most important agrometeorological indices. This can be useful in forecasting of sugarcane yield in advance in western Maharashtra.

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