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Modelling Saffron Yield Based on Weather Variables in the North East of Iran

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Khorasan Province is known as the major Saffron production area of Iran. In this study, Crop Weather Models were applied to predict Saffron yield in main production areas of the province (Birjand, Torbat Heidariye, Ferdows and Gonabad cities) by using 20 years data. Four predictors including temperature, rainfall, relative humidity and sunshine hours were considered for Model I, and two weather parameters including temperature and rainfall were used for Model II. These two models were applied using stepwise regression analysis and JMP statistical Software. The results indicated that the coefficients of determination of model I were higher than of model II. The results also showed that the models can predict Saffron yield in Gonabad city more precisely. The coefficients of determination for Gonabad were 0.77 and 0.74 for model I and model II respectively. The least coefficient of determination was 0.38 for model II in Torbat Heidariye. It was also concluded that during recent years the increasing trend in mean air temperature during the spring season was the main cause of Saffron yield decline across the province.

Key words: Crop-weather model, Saffron, Yield

I. INTRODUCTION

Year-to-year fluctuations in weather cause large variations in crop yields. Uncertainty in weather creates a risky environment for agricultural production. During the last decades the application of simulation and system analysis in agricultural research has increased considerably. Numerous crop growth and yield models have been developed for a wide range of purposes in the recent years. These models range in complexity from the most sophisticated simulators of plant growth, primarily intended for research in top plant physiological interactions, to multiple regression models using only a few monthly weather variables to forecast regional crop yields. Generally, plant-process yield models have been developed to predict yield at the level of an average plant in a specified field. The prediction of crop development is an important aspect of crop growth modeling. Crop weather models, in general, integrate current knowledge from various disciplines, including meteorology, crop physiology, plant breeding, and agronomy, into a set of mathematical equations to predict growth, development and yield (1). While the impact of Weather variability on yields are reported for several crops in Iran, but there has not been much works for Saffron. Saffron is a plant with wide ecological, physiological and phonological variations in comparing to other conventional cultivated. However, there is still a great deal of controversy related to ecological, phonological and standard type of climate for this plant (2). However, the influence of weather factor such as temperature has been studied for Saffron by some researchers. Behdani et al (2003) developed a model to predict Saffron flowering time in Iran. The objective of this study was to develop a thermal model that can be used for prediction of Saffron flowering time. They concluded that developing rate of Saffron have a unique response to mean air temperature of September (3). Molina et al (2004) considered the impact of air temperature on flower formation in Saffron in Spain. Their results showed that the number of flowers formed was maximal for corms incubated at 23 - 27°C (4). In this study, we tried to evaluate the trends of Saffron yield in the recent years and find the relationship between Saffron yield and climate variation for the main areas of Saffron cultivation in Khorasan province of Iran.

II. MATERIAL AND METHOD

The data of Saffron yield from 1983 to 2005 was collected from Khorasan Agriculture Organization. Table I shows the average of long-term Saffron yield in its period.

Table I. Average of Saffron yield in area under study

City	Average of Saffron yield (kg/ha)	Period (Year)
Birjand	5.66	21
Torbat Heidariye	3.92	22
Ferdows	5.16	22
Gonabad	4.77	22

Yield change trend was studied using time series analysis. This is a forecasting method that uses a set of historical values to predict an outcome. These historic values, often referred to as a "time series", are spaced equally over time and can represent anything from monthly to daily and hourly data. It is assumed that a time series is a combination of a pattern and some random errors. The goal is to separate the pattern from the error by understanding the pattern's trend, its long-term increase or decrease, and its seasonality, the change caused by

seasonal factors such as fluctuations in weather parameters and yield (5).
In time series the equations are showed in the linear and curvilinear forms (equations 1 and 2).

$$Y_t = b_1 + b_2 t + + e_t \quad (1)$$

$$Y_t = b_1 + b_2 t + b_3 t^2 + e_t \quad (2)$$

In which Y_t is a timely variable (here, Saffron yield per year), b is constant and e_t is the error for estimation Y in each year (6).

In this study, both linear and nonlinear (degree of a power of 2.) equations were fitted to yield data. Yield trend in time series was predicted for 5 years. In order to predict yield trend there are different methods including: moving average, double moving average, exponential smoothing and also Winters method. There are also some advanced method such as Auto-Regressive Moving Average (ARMA) and Auto Regressive Integrated Moving Average (ARIMA) that are used for specific data. In this study exponential smoothing was used, for predicting trend of Saffron yield.

III. EVALUATION OF CORRELATION BETWEEN YIELD AND WEATHER INDICES

In order to determine relationship of Saffron yield in the areas under consideration, weather parameters over 20 years data including monthly rainfall, monthly average of minimum and maximum air temperature, monthly average of air temperature, monthly average of minimum and maximum relative humidity, and monthly total of sunshine hour's were collected from database of Khorasan Climatology Center. In this research two models were used. All of the above mentioned weather parameters were applied in model I while only temperature and rainfall data were used in model II. The relationship between Saffron yield and weather parameters was determined by applying a simple and a multiple regression analysis. Saffron yield was correlated with monthly weather factors for all of the areas in order to determine climatic indicator for each station and also to determine the most important month affecting Saffron yield. Then, by multiple regressions analysis, Saffron yield was correlated to the most effective climatic variable in each area. The Backward Stepwise Regression model was used for this analysis. Thus, the final model describing yield was calculated by applying the most important climatic variables. The Minitab software, ver. 13.1 was used for the time series analysis and the JMP ver 4 was used for the regression analysis.

IV. RESULT AND DISCUSSION

Trend of Saffron yield in all of the areas is more or less similar. It was concluded that nonlinear (degree of a power of 2.) equations are more fitted to the trend of Saffron yield in the area. Therefore the equation of Saffron yield trend in Birjand, Torbat Heidariye, Ferdows and Ghaen are defined by equations 4 to 7, respectively. Figures 1 to 4 show the trend of Saffron yield for the areas of under this study.

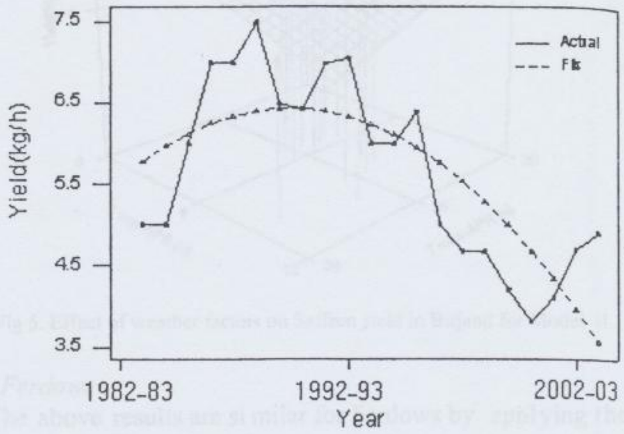

Fig 1. Trend analysis for Saffron yield in Birjand

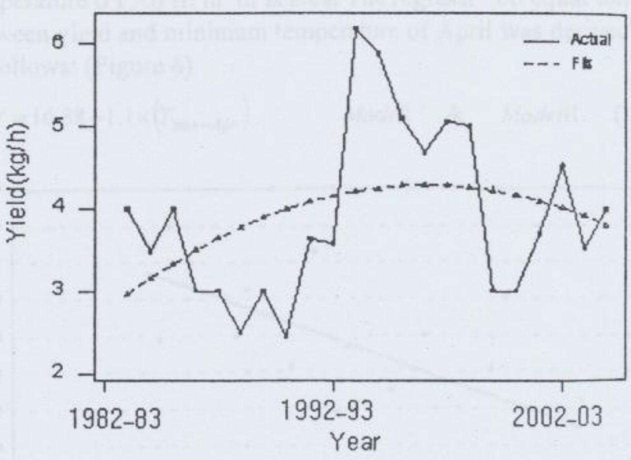

Fig 2. Trend analysis for Saffron yield in Torbat Heidariye.

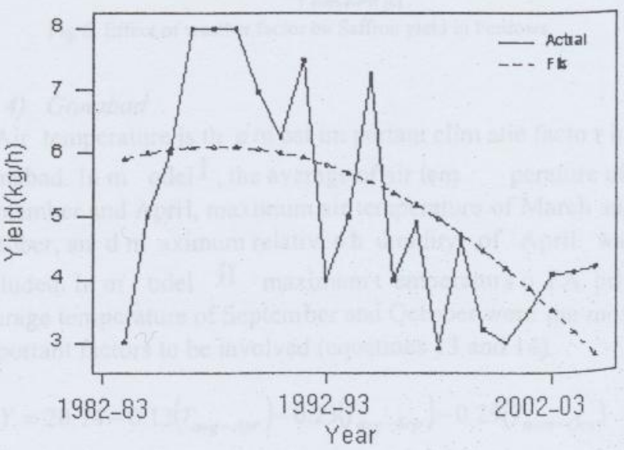

Fig 3. Trend analysis for Saffron yield in Ferdows

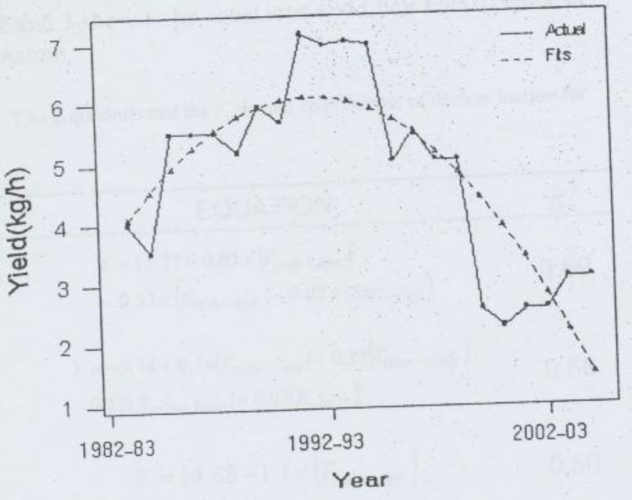

Fig 4. Trend analysis for Saffron yield in Gonabad.

Birjand $Y = 5.56 + 0.23(t) - 0.016(t^2)$ (4)

TorbatHeidariye $Y = 2.75 + 0.22(t) - 0.008(t^2)$ (5)

Ferdows $Y = 5.81 + 0.12(t) - 0.012(t^2)$ (6)

Gonabad $Y = 3.57 + 0.54(t) - 0.029(t^2)$ (7)

THE RELATION BETWEEN WEATHER VARIABLES AND SAFFRON YIELD

1) *Birjand*

Using stepwise technique in a regression analysis for 21 years weather data of Birjand showed that minimum and maximum air temperature of April and Sunshine hours of Feb have the most significant effect on Saffron yield. The regression equations for the two models are as following:

$$Y = 15.27 - 0.02 \times (T_{avg-Apr}) - 0.53 \times (T_{\min-Apr}) - 0.02 \times (Sun_{-Feb}) \quad ModelI \quad (8)$$

$$Y = 14.86 - 0.38 \times (T_{\min-Apr}) - 0.22 \times (T_{\max-Apr}) \quad ModelII \quad (9)$$

The results are shown in Figure 5.

2) *TorbatHeidariye*

The same analysis was run for Torbat Heidariye using 1983 to 2005 data. The results showed that minimum relative humidity of June is appeared to be different between the two models.

$$Y = -5.74 + 0.14(T_{\max-Jun}) + 0.17(T_{\max-July}) + 0.12(R_{\min-June}) + 0.01(P_{-Mar}) \quad ModelI \quad (10)$$

$$Y = -5.37 + 0.15(T_{\max-Jun}) + 0.24(T_{\max-July}) + 0.01(P_{-Mar}) \quad ModelII \quad (11)$$

Minimum relative humidity of June for Torbat Heidariye was the most important factor among the parameters.

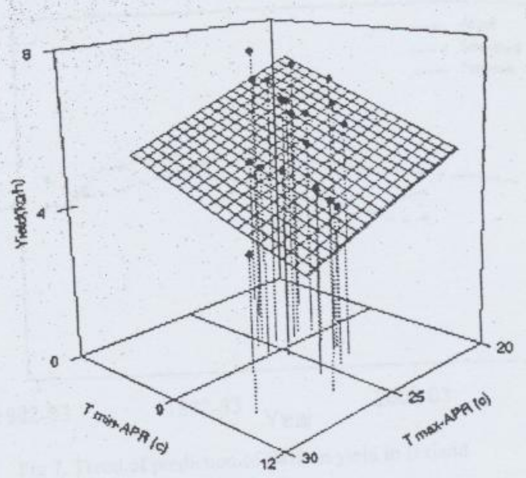

Fig 5. Effect of weather factors on Saffron yield in Birjand for Model II .

3) *Ferdows*

The above results are similar for Ferdows by applying the two models. The most important factor was minimum temperature of April in this area. The regression equation between yield and minimum temperature of April was derived as follows: (Figure 6)

$$Y = 16.88 - 1.1 \times (T_{\min-Apr}) \quad ModelI \quad \& \quad ModelII \quad (12)$$

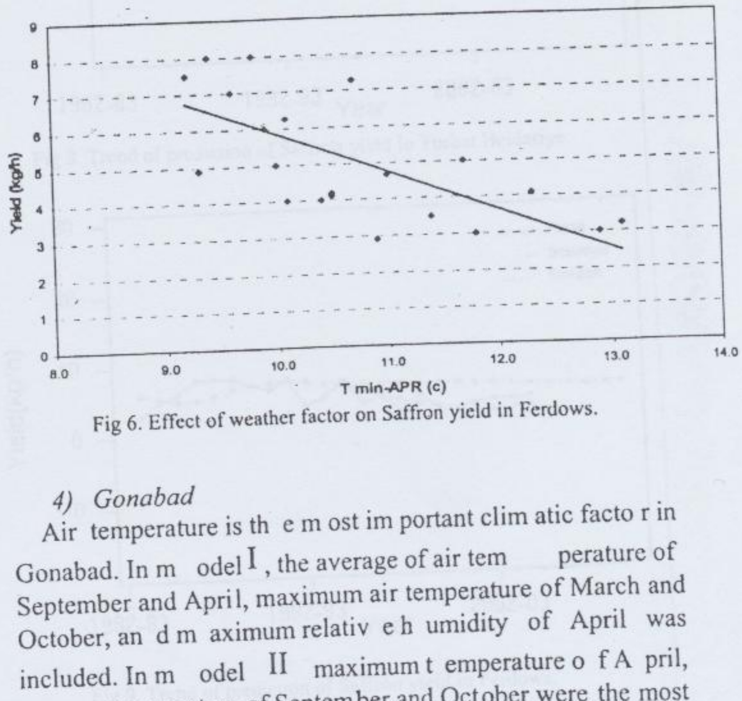

Fig 6. Effect of weather factor on Saffron yield in Ferdows.

4) *Gonabad*

Air temperature is the most important climatic factor in Gonabad. In model I , the average of air temperature of September and April, maximum air temperature of March and October, and maximum relative humidity of April was included. In model II maximum temperature of April, average temperature of September and October were the most important factors to be involved (equations 13 and 14).

$$Y = 20.74 - 0.13(T_{avg-Apr}) - 0.23(T_{avg-Sep}) - 0.29(T_{\max-Oct}) - 0.17(T_{\max-Mar}) + 0.05(R_{\max-Apr}) \quad ModelI \quad (13)$$

$$Y = 27.81 - 0.28(T_{avg-Oct}) - 0.29(T_{avg-Sep}) - 0.41(T_{\max-Apr}) \quad ModelII \quad (14)$$

Tables 2 and 3 show t he equat ions and t heir coeffi cients of determination.

Table II . T he E quations and the r elevant co efficients of determ ination for model I

CITY	EQUATION	R^2
Birjand	$Y = 15.27 - 0.02 \times (T_{avg-Apr}) - 0.53 \times (T_{\min-Apr}) - 0.02 \times (Sun_{-Feb})$	0.69
Torbat Heidariye	$Y = -5.74 + 0.14(T_{\max-Jan}) + 0.17(T_{\max-July}) + 0.12(R_{\min-June}) + 0.01(P_{-Mar})$	0.68
Ferdows	$Y = 16.88 - 1.1 \times (T_{\min-Apr})$	0.50
Gonabad	$Y = 20.74 - 0.13(T_{avg-Apr}) - 0.23(T_{avg-Sep}) - 0.29(T_{\max-Oct}) - 0.17(T_{\max-Mar}) + 0.05(R_{\max-Apr})$	0.77

Table III . The Equations and the relevant coefficients of determination for model II

CITY	EQUATION	R^2
Birjand	$Y = 14.86 - 0.38 \times (T_{\min-Apr}) - 0.22 \times (T_{\max-Apr})$	0.53
Torbat Heidariye	$Y = -5.37 + 0.15(T_{\max-Jan}) + 0.24(T_{\max-July}) + 0.01(P_{-Mar})$	0.38
Ferdows	$Y = 16.88 - 1.1 \times (T_{\min-Apr})$	0.50
Gonabad	$Y = 27.81 - 0.28(T_{avg-Oct}) - 0.29(T_{avg-Sep}) - 0.41(T_{\max-Apr})$	0.74

The coefficients of determ ination (R^2) shows quantity of yield variation which is descri bed by weat her fact ors. The Maximum and m inimum coeffi cients of det ermination (R^2) were 0.77 and 0.50 for Gona bad and Ferdows i n m odel I respectively. In model II Gonabad and Torbat Heidariye had the maximum and Minimum coeffi cients of det ermination (R^2) that are equal to 0.74 and 0.38 respectively.

Finally, yield trend was predi cted for the last 5 y ears using time series analysis. These results showed i n Figures 7 to 10. The trends of yield for th e last 5 years fo r 4 cities are descending (red line).

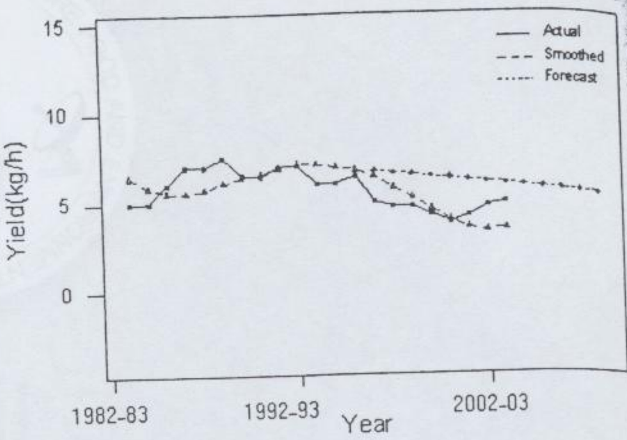

Fig 7. Trend of prediction of Saffron yield in Birjand

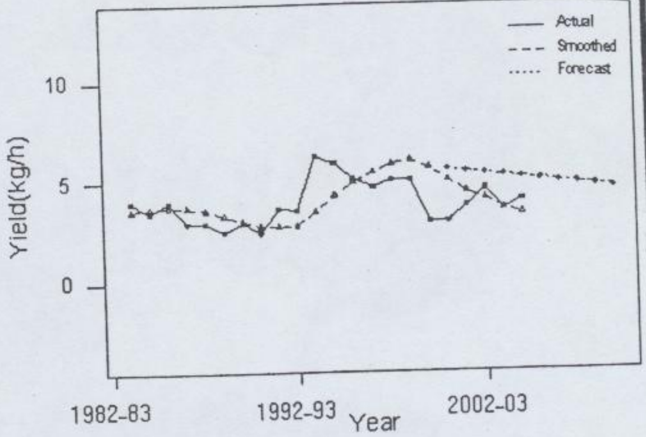

Fig 8. Trend of prediction of Saffron yield in Torbat Heidariye.

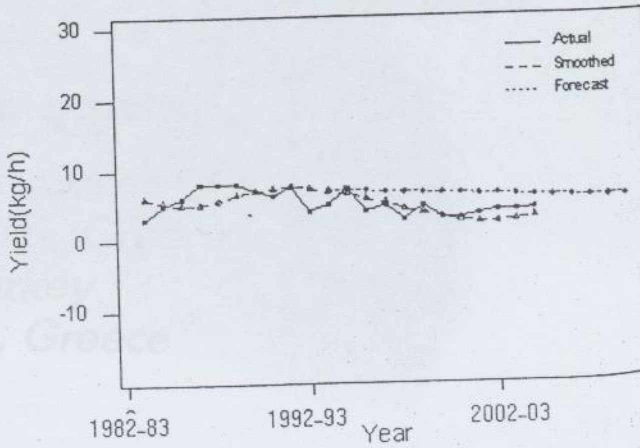

Fig 9. Trend of prediction of Saffron yield in Ferdows.