Seasonal Forecasting Activity

Temperature-Corn yield and the Application of Seasonal Forecasts in Central Iowa

Introduction

About half of the world's corn is produced in the USA (Shaw, 1977). And the major part of this production comes from the Midwest. Iowa, in the Midwest, is also a corn producer. Corn is mainly produced within certain climate zone. According to Shaw’s (1977) review of Trewartha’s climate claasification, the temperate continental climate zone with 4-7 summer months above 10^0C and with a hot summer of hottest month over 22^0C, coincides with the Corn Belt of the USA. It has been indicated that mid-summer temperatures of less than 19^0C and those very hot temperatures are not favorable for corn production. This indicates plant-temperature relationship and regions for production. Therefore it is important that factors affecting corn yield have to be studied. Many studies have been done in this respect. In the scope of this study the aim will be to look at the effect of temperature on corn yield during the growing season in Ames, central Iowa.

Studies indicate that different stages of corn plant are intimately related to climatic elements (Shaw, 1977; Carlson, 1990, Carlson et al, 1996). Amongst the influencing factors, temperature variation is known to be one limiting case. Studies show that growth and development of corn is very much limited and adversely affected if mean mid-summer temperatures are below 19^0C or equivalently, average minimum summer temperatures are below 13^0C. This is the limiting case for yield. Optimal temperatures are considered to be between 21 and 27^0C. Also studies show that temperature is an important factor at various stages of plant development. The anomalous fluctuation in precipitation and temperature affects plant even before planting as the soil moisture reserve is strongly impacted by temperature (Shaw, 1977). So, temperature determines planting dates. Shaw (1977) shows that average temperature reaching 12 to 14^0C is an important factor. Subsequent stages are also directly affected by temperature. Emergence of plant, in Ames, can be quicker in warmer ranges. Vegetative to flowering stages will be adversely affected, if temperatures drop below freezing lines. The late vegetative stages of plant development are markedly related to temperature as this matches with July in the Corn Belt. Studies show that July temperatures are negatively correlated to late vegetative stages. As a result, studies use regression techniques to investigate the effect of temperature on corn yield.

Therefore, it makes sense to investigate the relationship between the growing season temperatures and corn yield over years and look into the application of seasonal forecasts for corn agricultural activities. The objective of this work is, thus, (a) to examine the relationship between April, May, June, July and August temperatures and corn yield by developing a regression equation taking corn yield as dependent variable and those five months mean temperature as predictors, and (b) to examine the utility of the forecasting efforts, taking temperature forecasts, initialized at various months, and correlate with yield and develop an equation. Finally comparison will be made between the results obtained from the two regression equations, i.e., regression from climatological data and forecast data in the recent 10-year period.

The study is structured in 3 sections. The first being the introduction, section 2 presents some description on data and methods. Section 3 discusses the results.

II. **Data and methods:**

Monthly temperature at Iowa observatory from 1900 to 2000 and corn production data for the same period has been kindly provided by Dr. Carlson. Temperature hindcast data have been organized from the Seasonal Forecasting web site. Since the observed data is from Ames observatory, the hindcasts data have been interpolated among four-grid points for Ames.

The methods of the study include developing of correlation between corn and each of the growing season months and compare with earlier works (Carlson, 1990; Carlson et al. 1996). Since the combined effect would be more important than the single trend fit, a regression equation has been developed. It is assumed that these will take care of the effect of temperature on the plant at various stages and provides opportunity to see carried-over effect, if any. Regression equation of yield as a function of hindcast data has also been developed. Regression equations were developed using MINITAB V13 Software package.

III. **Discussion**

Figure 1 shows the time series variation of corn yield and April, May, June, July and August temperatures. It is seen that corn has been tremendously increasing over years. This is on the account of technology (improved inputs and well management condition) and other improved inputs. This may not clearly single out climate effects. Therefore the data have to be de-trended first. The de-trending process has been accomplished by adopting Dr. Carlson's trend line fit that has been used for the same purpose. This has not been adequate. To minimize the effect of error accumulation, anomalies are preferred. Consequently, using the trend line for the yield data and individual mean values for monthly temperatures, the anomaly data has been generated. Figure 2 depicts the relationship of each month's temperature anomaly against the fluctuation of production. This will help us in visualizing individual effects on yield.

Table 1 shows the correlation coefficients of months with crop yield. The correlation coefficients have been developed using the 1900-1980 data range. It is seen that July temperatures are more strongly related to yield. June temperatures are positively related to yield. This has been again seen using the 1954-1988 data set in which the relationship is seen to be negative.

Table 1. Correlation coefficients between Yield and monthly mean temperatures

	April	May	June	July	August
yield	-0.04052	-0.12572	0.064323	-0.35337	-0.17233

Regression equation developed from the observed data (based on 1980-89) is given by the following equation.

$$Y=-2.76-0.18T_{a}-1.34T_{m}-0.2T_{jn}+0.55T_{jl}-5.37T_{ag}$$

The regression equation developed using the hindcast data is also given below:

$$Y_{f}=-1.98+2.25T_{a}-2.04T_{m}-0.94T_{jn}+15.3T_{jl}-14.6T_{ag}$$

where Y and Y_f are corn yield, T_{ap}, T_m, T_{jn}, T_{jl} and T_{ag} are temperature anomalies of April, May, June, July and August, respectively.

Fig 3 show yield versus yield estimates based on the regression equation developed from observed data. These have been prepared to see how well the regressions have been captured the observed data series. In most of the cases, it is seen that yield fluctuation is captured.

Fig. 4 shows the time series fluctuation of hind casts. When these are compared with the time series fluctuation of monthly-observed temperatures of the same period, they are generally in good agreement.

Table 2 and figure 5 depict the estimates of monthly yield from the regression equations developed. As can be seen in figure 5, in most cases, the estimates perform the same way. This indicates that seasonal forecasts are important to consider in corn agricultural activity. Note that in some years the gap between climatological and hindcast-based data estimates.

Table 2. Estimates of corn yield from the regression equation developed using climatological data and hindcasts.

year	Estimates from observed (y)	Estimates from hindcast (y_f)	Differences ($y-y_f$)
1990	-1.561	-14.0333	12.47235
1991	-6.649	40.9467	-47.5957
1992	26.113	14.66954	11.44346
1993	1.058	-24.5662	25.62415
1994	5.681	15.98163	-10.3006
1995	-20.969	0.936206	-21.9052
1996	8.829	-7.23573	16.06473
1997	12.849	17.35325	-4.50425
1998	-21.998	-19.3171	-2.68089
1999	4.703	-11.3873	16.09026

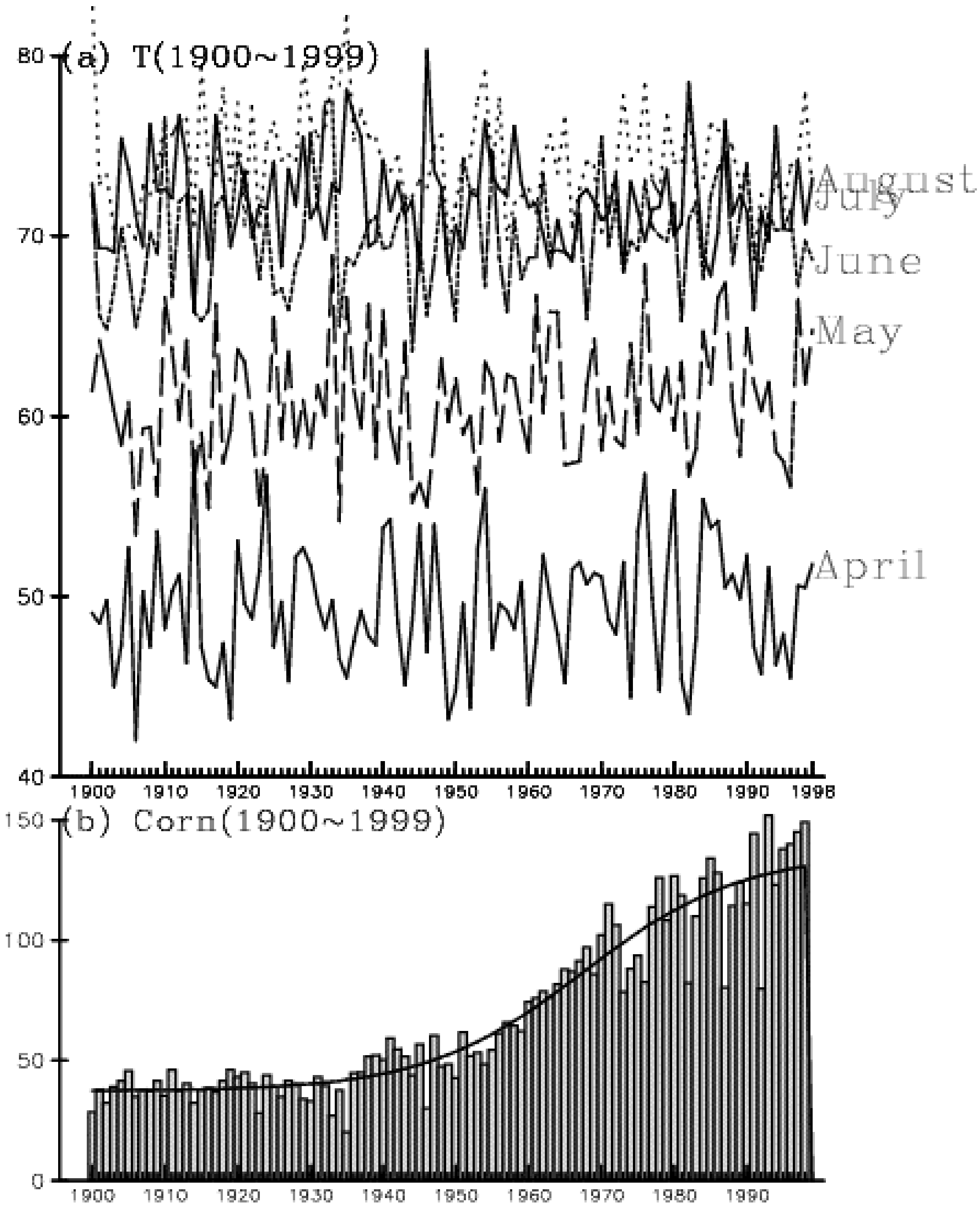

Figure 1 - Time series variation of corn yield and April, May, June, July and August temperatures.

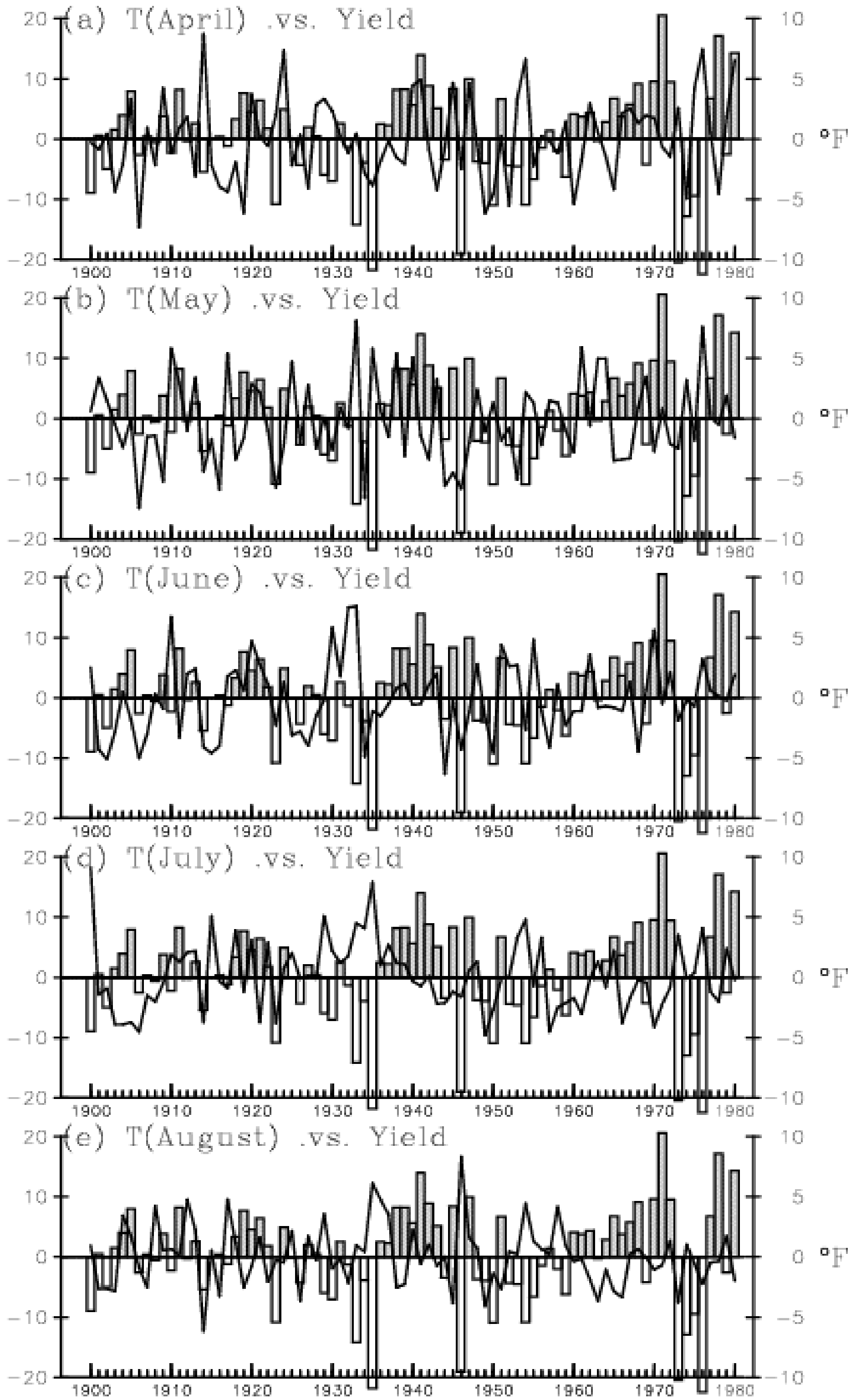

Figure 2 - Relationship of each month's temperature anomaly against the fluctuation of production.

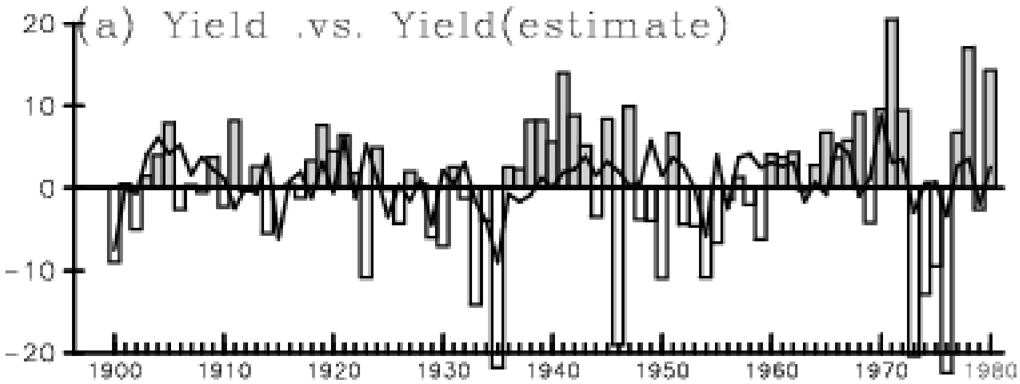

Figure 3 - Yield versus yield estimates based on the regression equation developed from observed data.

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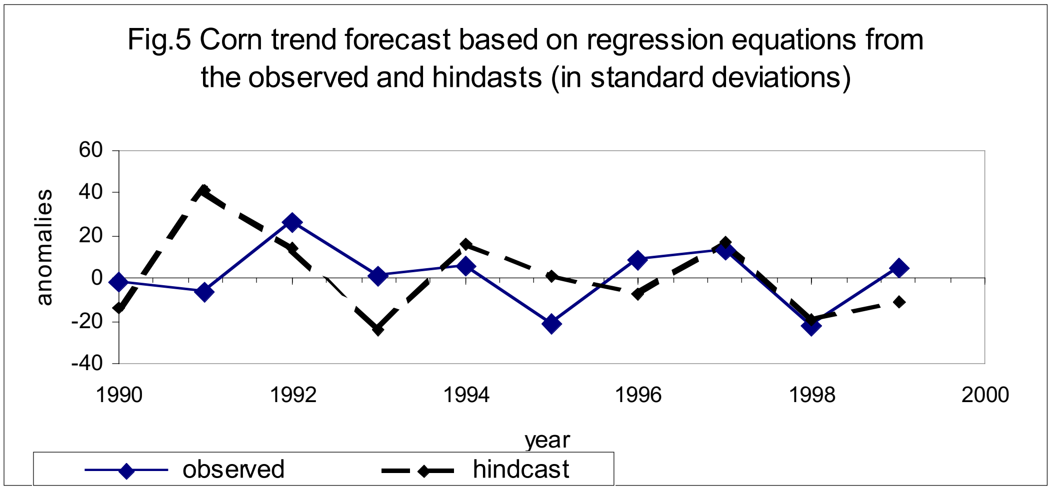
Fig. 4 - The time series fluctuation of hind casts



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