ADDENDUM TO A PAPER BY S. J. MAAS TITLED "FORECASTING YIELDS USING WEATHER RELATED INDICES," by Keith N. Crank; Statistical Research Division; Statistical Reporting Service; U. S. Department of Agriculture; Washington, D. C. 20250; May 1984.

ABSTRACT

The stratification techniques developed in Maas's paper are evaluated. Using F tests designed to compare different regression models, results indicate that the between year stratification (BYS) method of model construction does not explain the year to year variation in the data. Further, comparison of his within year stratification method (WYS) to his BYS method shows that neither technique improves on the objective yield procedure for forecast model building.

CONTENTS

FOREWORD

Stephen Maas conducted research for the Statistical Reporting Service (SRS) as an Intergovernmental Personnel Act (IPA) scientist from Texas A&M University. His results were publilshed in SRS Staff Report No. AGES820317, March 1982. The following abstract is from that report.

> "A technique for including the effects of weather in objective yield forecasts is developed and evaluated. The forms of the regression-type yield component models in current use are not changed. Rather, weather-related indices are developed to stratify historic objective yield data used to build the models. The objective is to stratify the data so that it will be more representative of growing conditions during the forecast year than the 3- or 5-year sequences of data selected using the current technique. Two stratification techniques are investigated—one in which conditions for individual years are compared to the forecast year and another in which sub-groups of data are selected from a pooling of all historic data. The proposed techniques are applied to seven years of winter wheat data from Kansas and the results of forecasts are compared to those made using the current technique."

This Addendum attempts to evaluate the techniques described by Maas. Commonly used and accepted statistical tests are used in this evaluation.

SUMMARY

Stephen Maas has presented two methods of incorporating weather variables in building models for forecasting crop yields. His between year stratification (BYS) Method identifies years whose weather patterns are similar at the state level. His within year stratification (WYS) method identifies similar weather patterns at the sample level.

This Addendum shows that neither of his stratification methods adequately explains the variation in the data. Statistical tests of the different regression models are made using an F statistic. Further comparisons of residual sums of squares are made when the F statistic is not valid.

INTRODUCTION

This addendum presents some statistical analyses which show that the weather-related indices considered in Maas's report do not adequately improve the current objective yield forecast model building procedure. The statistical techniques which could be used to analyze the summarized data in the report do not have the power to detect differences in regression models based on data from only seven years. Therefore, this analysis is based on the original data.

The idea of using weather variables to improve a regression model for forecasting yields is well worth considering. Questions arise, however, concerning how to incorporate weather variables into the model. Maas's paper presents two methods for incorporating weather variables in selecting data to build forecast yield models.

The first method classifies each year according to a specific index. Then the years chosen for computing the regression coefficients for the model are those years whose indices are closest to the index of the year for which a forecast is to be made. This method is called the BYS method in the paper. The indices used are April relative soil water, cumulative maximum temperature, and average stalk number per sample. In Maas's paper each of these indices was used individually, and also all combinations of two of these indices were used. Thus six possible models were compared.

The second method classifies each sample according to a specific index. The samples are then divided into groups according to their value of this index. Each of these groups determines a model and a forecast is made for each sample in the forecast year based on the group in which it has been classified. This method is called the WYS method in the paper and is used only with the April relative soil water index.

The method of analysis that I have used in this Addendum is to compare various linear regressions using F-tests. (See Neter and Wasserman, Applied Linear Statistical Models, 1974, Chapter 7). Since the methods presented in this paper and the current objective yield methods both forecast yield from linear regressions, we are only interested (in this analysis) in comparing various linear models. In what follows X will denote stalk counts and will be the independent variable in the model, while Y will denote the number of heads and will be the dependent variable, and the Greek letters (α, β, μ) will denote the regression coefficients of the model. Subscripts will be used to distinguish parameters within a model and variables which have been placed in subgroups.

In the analysis we will assume that we have a multiple linear regression with p parameters. We will want to test the hypothesis that a subset B of these parameters is zero. Our alternative will be that at least one element of B is non-zero. The model with p parameters is called the full model. The model which assumes the elements of B are zero is called the reduced model. We denote the corresponding model sum of squares by SSM_F and SSM_R respectively. If B contains q elements and SSE_F denotes the error sum of squares for the full model, then the quantity

$$\frac{(SSM_F - SSM_R)/(p-q}{SSE_F/(n-p)}$$

has an F distribution with (p-q) and (n-p) degrees of freedom. In each case this quantity will be used to test our hypothesis.

ANALYSIS I

The first analysis is of the BYS method. A between year stratification will improve the model only if the regression parameters are not the same from year to year. The first step, then, is to answer the question, "If a separate regression were run for each year, would the regression parameters be the same or different?" Consider the model $Y = \sum_{i=1}^{7} (\mu_i + \beta_i X_i)$ where the subscript i is used to distinguish years. We can answer our question by testing the hypothesis:

H: $\mu_1 = \mu_2 = \ldots = \mu_7$ and $\beta_1 = \beta_2 = \ldots = \beta_7$

against the alternative hypothesis

K: $\mu_i \neq \mu_j$ or $\beta_i \neq \beta_j$ for some $i \neq j$.

Lines one and two in Table 1 have the sums of squares, mean squared errors, and relevant degrees of freedom for the regressions based on the *two* hypotheses. Under the usual normality assumptions the difference between the model sums of squares (6,541,964 - 5,963,338 = 578,626) is distributed as a multiple of a chi-square random variable with 12 degrees of freedom and is independent of the error sum of squares from the full model, which is distributed as the same multiple of a chi-square random variable with 546 degrees of freedom. The F-statistic

$$F(12,546) = \frac{578,626/12}{7,663} = 6.29$$

can be used to test the hypothesis H against the alternative K. Since its P-value is less than .001, we reject the hypothesis H. Therefore, we conclude that the regression parameters are different between years.

Table 1: Model Sums of Squares, Degrees of Freedom, and Mean Squared Errors

Model	Model D. F.	Sum of Squares	Error D. F.	Mean Squares Error
1. Common slope and intercept for all subsets of the data	1	5,963,338	558	8,535
2. Different slope and intercept for each year	13	6,541,964	546	7,663
3. Slopes and intercepts depending on yearly average April relative soil water (BYS)	5	6,089,627	554	8,369
4. Slopes and intercepts depending on sample relative soil water (WYS)	5	6,288,105	554	8,011

Since there are differences in the regressions from year to year, we can try to separate the years into groups whose regressions are similar. Using the average April relative soil water from Figure 8 in Maas's paper, I would form three groups as follows:

(1) 1977, 1978;
(2) 1974, 1975, 1976;
(3) 1979, 1980.

Line three of Table 1 has the sum of squares, mean squared error and associated degrees of freedom for a regression model based on this grouping of years. When compared with line one, this model explains more of the variation in Y than the model which assumes a common slope and intercept for all years.

$$(F(4, 554) = \frac{(6{,}089{,}627 - 5{,}963{,}838)/4}{8369} = 3.77,$$

P-value $\approx$ .005). However, the model does not sufficiently explain the between year variation (comparing with line 2,

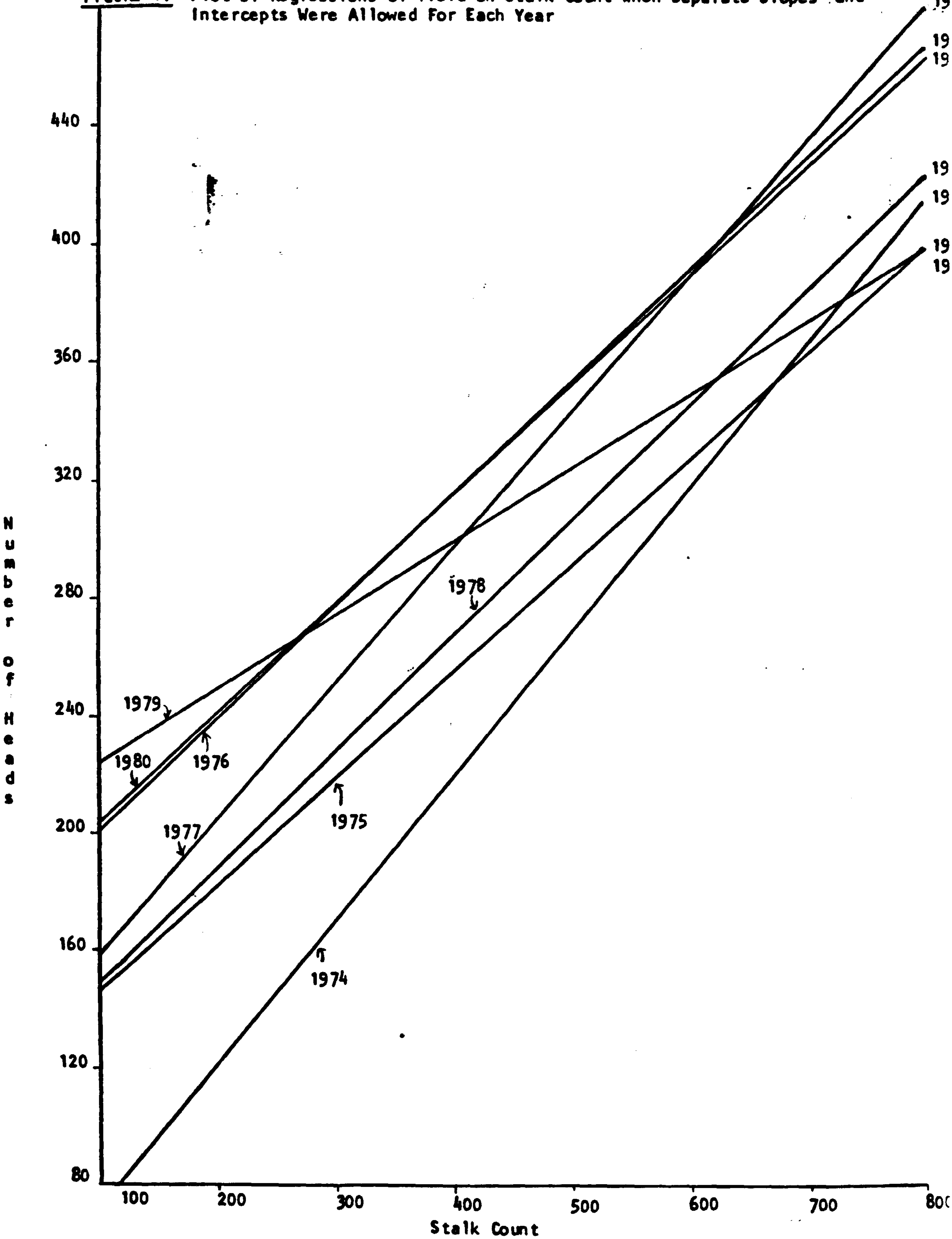
$$F(8,546) = \frac{(6{,}541{,}964 - 6{,}089{,}627)/8}{7{,}663} = 7.38, \text{ P-value} < .001).$$

Figure 1 is a plot of the fitted regression lines assuming there is a different slope and intercept each year. We have seen by the analysis presented in the preceeding paragraph that we cannot replace these seven lines by only three lines based on April relative soil water. In fact, we cannot replace these seven lines with three lines no matter how they are grouped. However, almost any grouping will be an improvement over a single line. Furthermore, if we divide the seven years into more than three groups, there are not enough years of data to provide reliable statistical tests. Therefore, there is no reason to believe that the BYS method presented in Maas's paper would be an improvement over current objective yield methods.

ANALYSIS 2

For the WYS method the data are divided into three groups according to the relative soil water (RSW) available for each sample. Plots with RSW values less than .2 were grouped together; plots with RSW between .2 and .6 were grouped together; and plots with RSW greater than .6 were group together. (This is Maas's stratification). The regression sum of squares is shown in line four of Table 1. Comparing this with line one, we can see that this model explains more of the variation than the model which has a single line ($F(4,554) = 10.14$, P-Value < .001); however, a comparison with lines two and three shows that this model is only slightly better than the BYS method using April relative soil water and does not explain as much of the variation as the model which has a separate line for each of the seven years. Other indices, though, may produce a better within year stratification than RSW. This cannot be determined from the report or the available data. Further work in this area may be useful.

FIGURE 1: Plot of Regressions of Yield on Stalk Count When Separate Slopes and Intercepts Were Allowed For Each Year



CONCLUSIONS

Based on the comparisons made here, none of the weather indices used in the paper do an adequate job in improving the current model used in the operating program. If further research is to be done in this area, the results should be presented in a form which allows a direct comparison with the current objective yield. This comparison should include either tests of hypotheses or the data from which these tests can be made. To do this will probably require a large number of years of objective yield data.