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ARGENTINA CORN YIELD MODEL

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16. Abstract

A model based on multiple regression was developed to estimate corn yields for the country of Argentina. A meteorological data set was obtained for the country by averaging data for stations within the corn-growing area. Predictor variables for the model were derived from monthly total precipitation, average monthly mean temperature, and average monthly maximum temperature. A "trend variable" was included for the years 1965 to 1980 since an increasing trend in yields due to technology was observed between these years.

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INTRODUCTION

The purpose of this study was to select monthly weather variables that could be used to estimate yields of the Argentina corn crop. The corn-growing area in Argentina is indicated in Figure 1. Most of Argentina's corn is grown in a concentrated area in central Argentina where the climate is predominantly humid subtropical. The western edge of the soybean area in central Cordoba is semi-arid with warm to hot summers. There drought and high temperatures can be a problem during the growing season which begins with planting in October and November and extends to harvest in April through June.

METHOD

Multiple regression analysis of yield with selected agroclimatic indices was used to derive a suitable model. The regression equation for the corn model derived is:

$$\hat{Y} = \alpha + B_1 T + B_2 (ETMETH_i) + B_3 (TX_i) + E$$

where

$\hat{Y}$ = Estimated yield

α = Constant

B_j = Coefficients of the variables j = 1 - 3

T = Trend 1965-1980

$ETMETH_i$ = $ET - \hat{ET}$ for month i: where $\hat{ET} = K \cdot PET$ and $K = \overline{ET}/\overline{PET}$.

TX_i = Maximum temperature for month i, and

E = Unexplained error.

Trend between the years 1965 and 1980 was determined from a plot of yields as shown in Figure 2. ET (evapotranspiration) minus $\hat{ET}$ (climatically appropriate evapotranspiration) was used as an index representing soil moisture for plant growth. A more complete definition is given in the Appendix. Large positive $ET - \hat{ET}$ values suggest wet conditions.

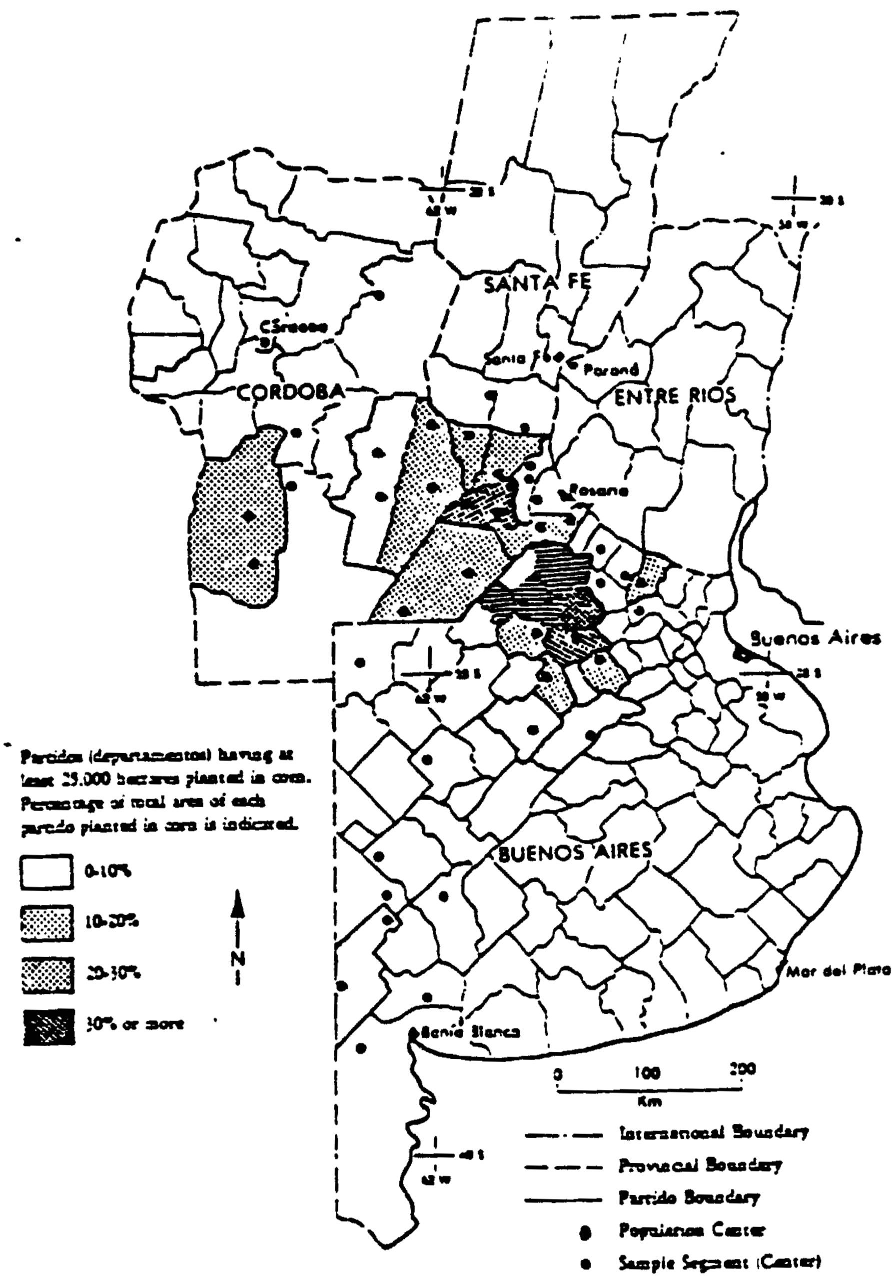
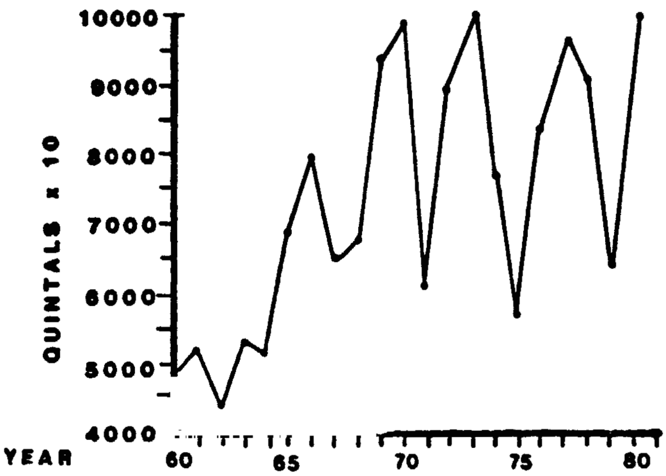
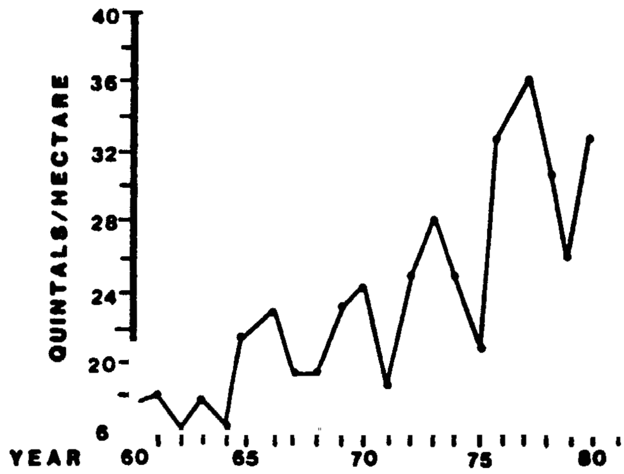


Figure 1. DENSITY OF PLANTED AREA IN CORN 1977/78 CROP YEAR (Source: "Agronomic Characterization of the Argentina Indicator Region")



CORN PRODUCTION



CORN YIELDS

Figure 2. Plots of Production and Yield Versus Year for Argentina Corn.

In developing the models, various procedures of the Statistical Analysis System (SAS Institute, Inc., 1979) were used. The procedures used and the operations performed with each are summarized in the Appendix. The selected model had the highest R^2 and included variables that were significant at the 10 per cent level and were agronomically meaningful.

DATA

Crop data for Argentina from 1960 to 1979 was obtained from the Foreign Agricultural Service (Alan Vandagrith, personal communication, 1982). A data set was created with year of yield as year of planting. Since the growing season spans two numerical years, the crop data was expressed in terms of "year + 1" (or harvested year) and the meteorological data corresponding to any yield included data for that year and "lagged" data for the previous year.

The meteorological data was created using the general Argentina meteorological station file. This file was composed of data from several different sources, including the Monthly Climatic Data for the World and the Servicio Meteorological Nacional in Argentina (R.E. Jensen, C.M. Sakamoto, and S.E. Mummert; August, 1974). Stations inside the corn-producing area were averaged by province and weighted according to the percentage that their province contributed to the entire country's production. Figure 3 shows the corn-growing area in Argentina and associated stations; Table 1 lists the stations used and their weights.

The years between 1961 and 1980 (year of harvest) were used in the model since these years contained the most complete meteorological data.

PROCEDURES

Weather variables were selected from correlations and plots with yield. These variables, along with TREND, were tried in regression equations. The limited number of data years severely limits the number of variables that

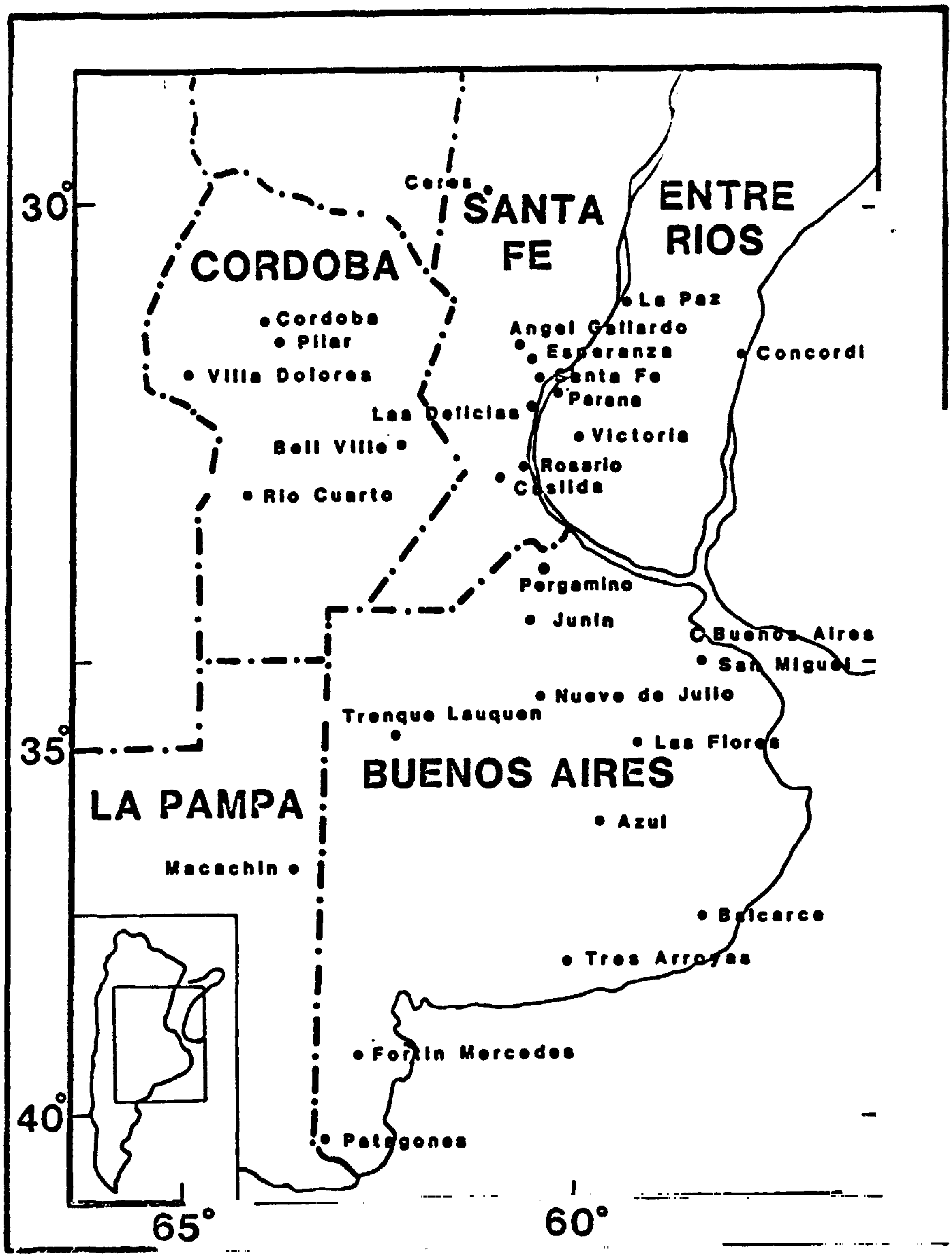


Figure 3. Five major agricultural provinces in Argentina

STATION NAME	WEIGHT
BUENOS AIRES	.50
Pergamino	
Junin	
Nueve de Julio	
CORDOBA	.27
Rio Cuarto	
Bell Ville	
SANTA FE	.23
Rosario	
Casilda	
Las Delicias	
Parana	
Pergamino	

Table 1. Meteorological Stations Used for the Argentina Corn Model.

can be included in a regression model by limiting the number of degrees of freedom. This influenced the choice of model considered "best" for soybeans. Three weather variables plus TREND were considered the optimum model with 19 years of data. The three weather variables are:

ETMETH11..............ET - $\hat{ET}$ for November

TX12..................Maximum temperature for December

TX1...................Maximum temperature for January.

The coefficient for the November variable was positive which reflects moisture requirements just after planting. The coefficients for maximum temperature for December and January were negative indicating that temperatures too high in the peak summer months during the tasselling and silking stages lead to stress on the plant. There is a critical growth period for corn. The statistics of the selected model are summarized in Table 2.

TEST RESULTS

A jackknife test was run on the model. In this test a year was eliminated from the crop data and the model was used to predict that year's yield. This process was done for each successive year beginning with 1961. The results were reasonable with the greatest difference (3.24 quintals) between predicted and actual yield in 1976. That year severe drought badly damaged the corn crop and harvest was hampered by rains. Test results are printed on Table 3 and plotted on Figure 4.

APPENDIX

Definition of Variables

The difference between ET and ET is an index of the amount of moisture available for plant growth. Soil moisture depletion is based on evapotranspiration (ET) estimates, determined as follows:

$$(ET)_n = \frac{(S)_{n-1}}{AWC}\left[\{(PET)_n - (P)_n\} + (P)_n\right]$$

where

$(ET)_n$ = "Actual" evapotranspiration,

$(S)_{n-1}$ = Available moisture at end of n-1 month,

AWC = Maximum water holding capacity,

$(P)_n$ = Precipitation for month n, and

$(PET)_n$ = Potential evapotranspiration for month n.

$ET - \hat{ET}$ measures the difference between the actual evapotranspiration and the "climatically appropriate" evapotranspiration, giving an indication of soil moisture supply and demand.

Statistical Analysis System Procedures Used

PROC CORR	Computes correlation coefficients between variables, including Pearson product-moment and weighted product-moment correlation.
PROC PLOT	Graphs one variable against another, producing a printer plot.
PROC STEPWISE	Provides five methods for stepwise regression. Stepwise is useful when selecting variables to be included in a regression model from a collection of independent variables.
PROC STEPWISE FORWARD	Begins by finding the one-variable model that produces the highest R^2. For each of the other independent variables, FORWARD calculates F-statistics reflecting the contribution to the model if the variable were to be included.

PROC STEPWISE BACKWARD	Begins by calculating statistics for a model including all the independent variables. The variables are deleted from the model one by one until all the remaining variables produce F-statistics significant at the .10 level.
PROC STEPWISE STEPWISE	The stepwise method is a modification of the forward selection technique, differing in that variables already in the model do not necessarily stay there. After a variable is added (as in the forward selection method) the stepwise method looks at all the variables already included in the model and deletes any variable that does not produce an F-statistic significant at the .10 level. Only after this check is made and the necessary deletions accomplished can another variable be added to the model.
PROC STEPWISE MAXR	(Maximum R^2 improvement) Unlike the three techniques above, this method does not settle on a single method. Instead it looks for the "best" two-variable model, the "best" three variable model, and so forth.
PROC PETM	Uses latitude and mean monthly temperature to calculate Thornthwaite's potential evapotranspiration for each month.
PROC ZINDEX	Uses monthly PET's, precipitation, SS (beginning moisture in surface layer), AWCS (available water capacity in surface layer, SU (beginning moisture in the underlying layer), and AWCU (available water capacity in the underlying layer) to calculate Palmer's soil moisture budget, drought index Z, ET, and ÊT.

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BACKWARD ELIMINATION PROCEDURE FOR DEPENDENT VARIABLE YIELD

ALL VARIABLES [illegible]   R SQUARE = 0.97880716   C(P) = 5.00000000

	DF	SUM OF SQUARES	MEAN SQUARE	F	PROB>F
REGRESSION	4	151.29895507	37.82473902	18.13	0.0001
ERROR	10	20.86504393	2.08650439		
TOTAL	14	172.16400000			

	B VALUE	STD ERROR	TYPE II SS	F	PROB>F
INTERCEPT	71.15[illegible]18162				
[illegible]	0.79779333	0.16530482	48.59797920	23.29	0.0007
[illegible]	0.52422337	0.27131535	7.90865410	3.79	0.0802
[illegible]	-0.52183260	0.25197426	8.91427490	4.27	0.0656
TX1	-1.28277170	0.44047491	17.69568470	8.48	0.0155

[illegible]ABLES IN THE MODEL ARE SIGNIFICANT AT THE 0.1000 LEVEL.

Table 2. Statistics of Argentina Corn Model.

ARGENTINA CORN ACTUAL YIELD AND MODELS PREDICTION 1961-1976.
A=ACTUAL YIELD
P=MODELS YIELD

OBS	BETA1	BEGMODYR	ENDMODYR	YIELDYR	YIELD	OBSYIELD	RSQ	DIFF	#PRES
1	75.0450	1963	1976	1962	20.1252	18.9	0.880524	0.13690	9
2	71.2483	1962	1976	1963	18.5123	16.5	0.881869	0.17984	9
3	71.4340	1962	1976	1964	18.3115	18.0	0.871191	0.36874	9
4	73.4300	1962	1976	1965	16.1879	16.8	0.862704	1.19942	9
5	70.7485	1962	1976	1966	21.3013	21.5	0.878957	0.74185	9
6	68.4572	1962	1976	1967	21.0233	23.2	0.899996	0.12056	9
7	77.6106	1962	1976	1968	17.0603	19.6	0.897215	1.02041	9
8	65.0327	1962	1976	1969	21.5440	19.3	0.897751	0.58304	9
9	70.8773	1962	1976	1970	22.6700	23.3	0.878422	1.00771	9
10	71.6006	1962	1976	1971	24.6503	24.4	0.871217	1.32123	9
11	78.6611	1962	1976	1972	15.9850	18.6	0.891779	2.11385	9
12	71.0345	1962	1976	1973	25.7065	25.2	0.867443	0.32200	9
13	72.8825	1962	1976	1974	25.4280	28.4	0.854961	1.31876	9
14	70.6842	1962	1976	1975	24.9080	25.1	0.867055	4.77654	9
15	65.3575	1962	1975	1976	24.4410	21.2	0.918661	0.92557	9

OBS	BETA2	BETA3	BETA4	BETA5	COMPTB1	COMPTB2	COMPTB3	COMPTB4	COMWTB5
1	0.738648	0.489291	-0.40070	-1.4205	75.0450	0.7386	0.6656	-13.[illegible]	-42.188
2	0.748467	0.520183	-0.50143	-1.2958	71.2483	0.7685	0.5282	-14.[illegible]	-37.700
3	0.790051	0.520463	-1.55381	-1.2677	71.4340	0.7901	0.3677	-14.[illegible]	-37.425
4	0.793869	0.517553	-0.50277	-1.3033	73.4300	0.7738	0.4062	-14.[illegible]	-40.365
5	0.801710	0.533042	-0.51206	-1.2716	70.7485	1.6034	0.4365	-13.[illegible]	-37.492
6	0.803565	0.525716	-0.64475	-1.2655	68.4572	2.4110	0.5045	-12.[illegible]	-33.247
7	0.842694	0.479377	-0.71463	-1.3122	77.6106	3.3708	0.0162	-22.[illegible]	-40.941
8	0.881497	0.659460	-0.58929	-1.0176	65.0327	4.4075	0.6912	-16.[illegible]	-31.851
9	0.805661	0.499557	-0.57635	-1.2172	70.8773	4.8340	0.4405	-17.[illegible]	-35.785
10	0.796139	0.526247	-0.51890	-1.2024	71.6006	5.5730	-0.4175	-15.[illegible]	-3[illegible]
11	0.837944	0.718135	-0.60733	-1.4512	78.6611	5.7028	-3.3239	-19.[illegible]	-4[illegible]
12	0.819474	0.564208	-0.52080	-1.2747	71.0345	7.3753	0.4428	-15.[illegible]	-37.732
13	0.630609	0.324627	-0.40646	-1.4207	72.8825	5.3061	0.2454	-11.[illegible]	-42.051
14	0.796315	0.547663	-0.50513	-1.2758	70.6842	8.7595	-2.5763	-14.[illegible]	-37.764
15	0.871681	0.523801	-0.33761	-1.2100	65.3575	10.4602	-1.6709	-12.[illegible]	-35.781

Table 3. Results of Jackknife Test for Argentina Corn Model.

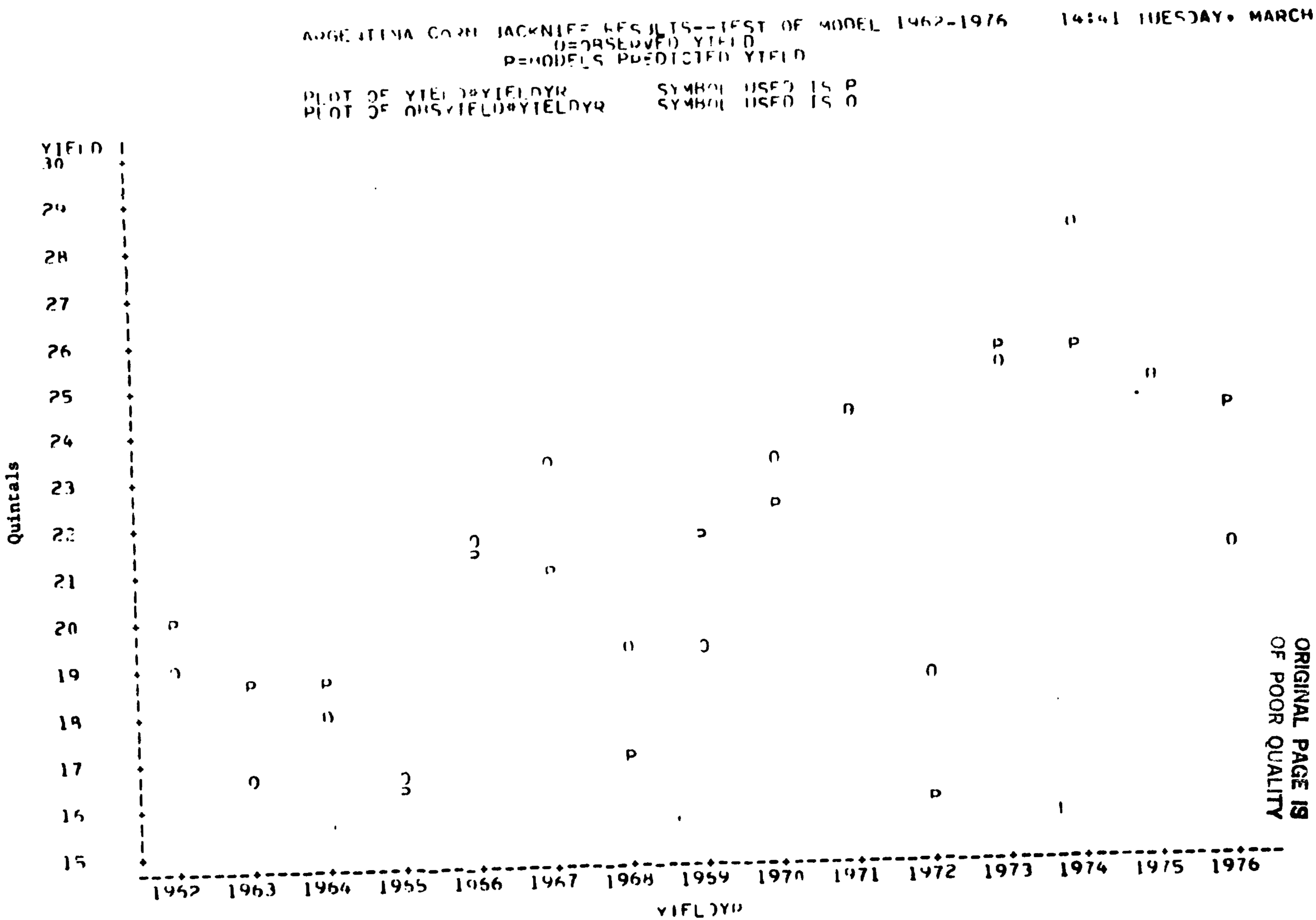

Figure 4. Argentina Corn Model.