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Yield Model Development

JANUARY 16, 1984

ARGENTINA WHEAT YIELD MODEL

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CLARENCE SAKAMOTO

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16. Abstract

Five models based on multiple regression were developed to estimate wheat yields for the five wheat-growing provinces of Argentina. Meteorological data sets were obtained for each province by averaging data for stations within each province. Predictor variables for the models were derived from monthly total precipitation, average monthly mean temperature, and average monthly maximum temperature. Buenos Aires was the only province for which a "trend variable" was included because of increasing trend in yield due to technology from 1950 to 1963.

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ARGENTINA WHEAT YIELD MODELS

by

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and

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AISC Models Branch

January 16, 1984

INTRODUCTION

The purpose of this study was to select monthly weather variables that could be used in models to predict wheat yields for the five main wheat-growing provinces of Argentina: Buenos Aires, Cordoba, Entre Rios, La Pampa and Santa Fe (see Figure 1). Each province was treated as a separate entity.

Most of Argentina's wheat-growing area is located in a humid subtropical climate known as the Pampa Humida. High temperatures in the winter can have an adverse effect on the wheat yield in the northern sections. Excessive rainfall in Entre Rios, where annual rainfall ranges from 900 to 1100 mm, can also be a problem during the growing season. The western edge of the wheat area, however, is semi-arid with warm to hot summers. There, drought and high temperatures can be a problem during the growing season.

Wheat is planted from early May through July. Harvest is generally from November through January.

METHOD

Three indices representing available soil moisture, monthly precipitation, and monthly maximum temperature (Sakamoto, 1976) were used in multiple regression models. They include: monthly Z-index, ET (evapotranspiration) minus ET (climatically appropriate evapotranspiration), and precipitation minus PET (potential evapotranspiration). Terms are defined in the Appendix. Large positive Z-index, P-PET, and ET-ET values suggest wet conditions.

The regression equation is:

$$\hat{Y} = \alpha + B_1 T + B_2 TX_i + B_3 R_i + B_4 Z_i + B_5 (P\text{-}PET)_i + B_6 (ET\text{-}\hat{ET})_i + E$$

where

$\hat{Y}$ = Estimated yield,

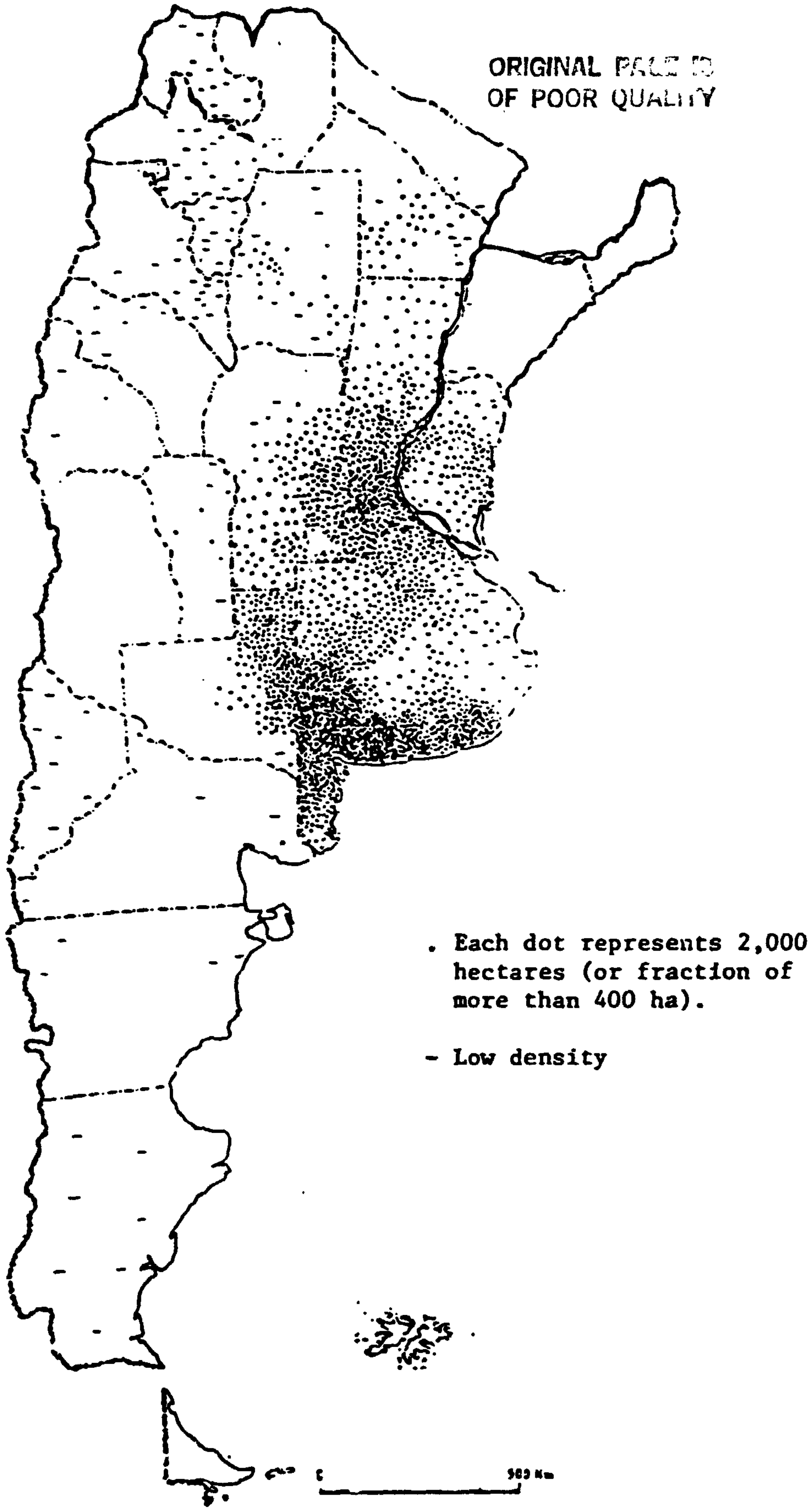

Figure 1. Density of area sown to wheat in Argentina, 1971-72. (Total area in wheat: 4,986,000 ha)

α = Constant,

B_j = Coefficients of the variables j = 1-6,

T = Trend,

TX_i = Maximum temperature for month i,

R_i = Total precipitation for month i,

Z_i = Z-index for month i,

$(P\text{-}PET)_i$ = Precipitation minus PET for month i,

$(ET-\hat{ET})_i$ = ET minus $\hat{ET}$ for month i, where $\hat{ET} = K \cdot PET$ and $K = \overline{ET}/\overline{PET}$, and

E = Unexplained error.

Separate data sets were used for each province. Variables tried and selected for each model differed according to the climate and agricultural practices of each province. Buenos Aires was the only province for which a trend variable was included.

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 listed in the Appendix. Combina ions of variables with the highest R^2 which included variables significant at (or close to) the 10 percent level and those agronomically meaningful were chosen for the models.

DATA

The Argentina crop data were obtained through the Latin American Branch of the Economic Research Service of the United States Department of Agriculture (M. Mielke, personal communication, 1980. The crop data set used was set up with the year of yield as the year of harvest. The growing season in Argentina may extend into January of the following year before harvest begins. Our interest is in the year of planting and when the weather impacts the crop, which in this case would be year-1.

Meteorological data were prepared using several different sources, including 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). The years between 1950 and 1970 were used to model since the greatest number of stations had the most complete meteorological data for these years. From a general meteorological data file of Argentina stations, separate data sets were created for each of the five wheat provinces. Table 1 lists the stations and weights used to derive each meteorological data set. Groups of stations were weighted according to the contribution of their area to the country's wheat production. Figure 2 shows the location of each station.

YIELD MODELS

Buenos Aires

A plot of yield vs. year for Buenos Aires reveals an increasing trend in technology from 1950 to about 1963 (see Figure 3). Therefore, a "trend variable" was chosen for this period.

The model for Buenos Aires was one of the most difficult to define, probably because this province covers such a large territory. Plots of possible weather variables versus detrended yield did not indicate any significant linear relationships. Variables that one would be inclined to choose on the basis of crop calendar and critical weather during growing season did not show strong correlations with yield.

After trying many combinations of variables in regressions, the following model was selected:

Linear Trend 1950-1963
ETMETH4................................April ET minus $\hat{ET}$
R7.....................................July total precipitation
ZINDEX8................................August Z-index
TX9....................................September average maximum temperature.

The signs of the coefficients of the model seem reasonable. The negative coefficient in July indicates too much rain during planting has a negative

<u>BUENOS AIRES</u>	
Pergamino	
Junin	
San Miguel	
Buenos Aires	Averaged and weighted 25%
Nueve de Julio	
Trenque Lauquen	
Las Flores	
Patagones	
Fortin Mercedes	
Tres Arroyas	Averaged and weighted 55%
Trenque Lauquen	
Macachin	
Azul	
Tres Arroyas	Averaged and weighted 20%
Balcarce	
<u>CORDOBA</u>	
Pilar	
Bell Ville	Averaged
Rio Cuarto	
Trenque Lauquen	
<u>ENTRE RIOS</u>	
La Paz	
Concordia	
Parana	Averaged
Las Delicias	
Victoria	
<u>LA PAMPA</u>	
Patagones	
Santa Rosa	
Macachin	
General Acha	Averaged
Fortin Mercedes	
Victorica	
Trenque Lauquen	
<u>SANTA FE</u>	
Ceres	
Esperanza	Averaged and weighted 23%
Angel Gallardo	
Bell Ville	
Bell Ville	
Rosario	Averaged and weighted 77%
Casilda	
Pergamino	

Table 1. Meteorological Stations and Weights Used to Develop Regression Models for Argentina Wheat

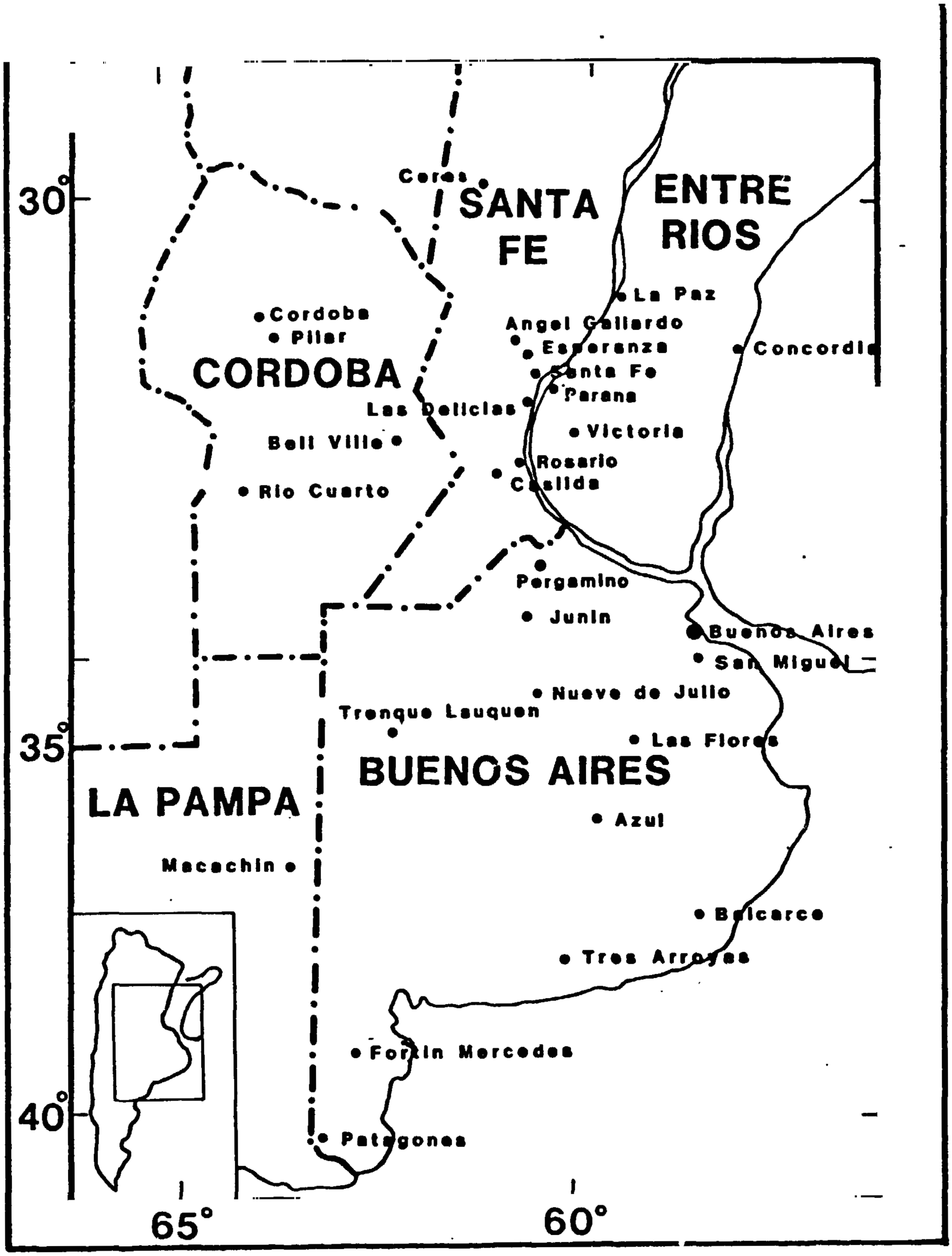

Figure 2. Five major agricultural provinces in Argentina and locations of meteorological stations used in model development.

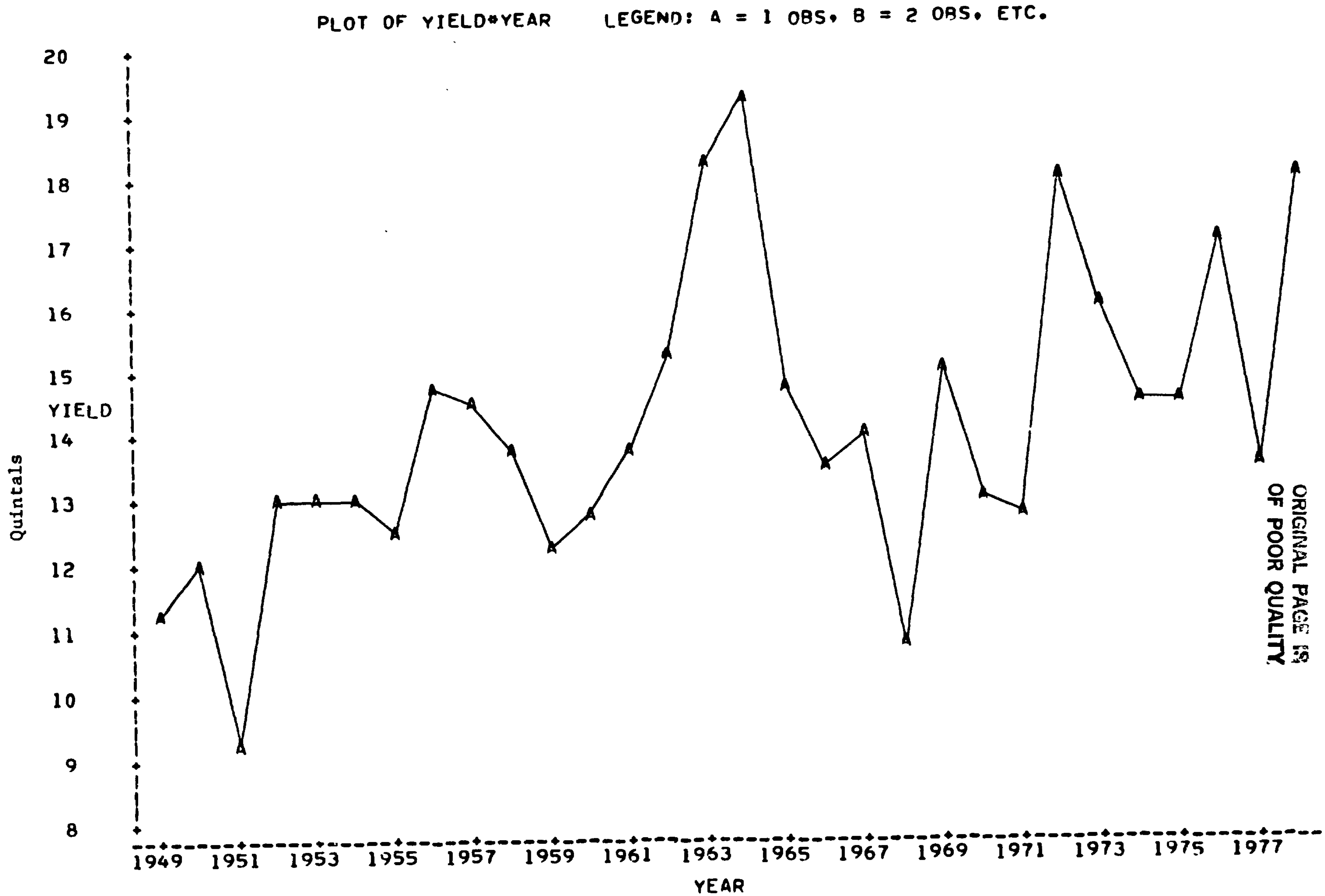

Figure 3. Plot of Yield Versus Year for Province of Buenos Aires.

effect on yield. A large, positive Z-index in August during jointing is favorable to yield. High temperatures in September during heading reduce yield. The statistics of the selected model are summarized in Table 2. A plot of the model's predicted yields and the actual yields for 1950-1970 is shown in Figure 4.

Cordoba

For Cordoba, plots of possible weather variables vs. yield showed that 1951 was a "pivot point" in determining linear relationships for most of the variables. Since yield for 1951 was extremely low, it was decided to plot the variables without 1951. No improvements was seen; there were even fewer linear relationships. Therefore, it was decided to retain 1951.

Initial variables were chosen on the basis of correlation with yield and were tried in regression equations. Models were tried with several combinations and squares of some of the variables. The following variables were significant as a model:

ETMETH5S................................May ET minus $\hat{ET}$ squared
TX7.....................................July average maximum temperature
P-PET8..................................August precipitation minus PET
ETMETH90S...............................September-October average ET minus $\hat{ET}$ squared.

The coefficient for ETMETH5S was negative, which reflects the need for drier conditions at planting time. The coefficient for ETMETH90S was also negative. This reflects the detrimental effects of excessive spring rains. High temperatures at early growth (July) reduces yield; favorable rain after planting (August) helps the crop get a good start. The statistics of the selected model are summarized in Table 3. A plot of the model's predicted yields and the actual yields for 1950-1970 is shown in Figure 5.

Entre Rios

Entre Rios was similar to Buenos Aires in that plots of weather variables versus yield did not produce any obvious linear relationships or strong correlations. Regression equations containing moisture variables consistently produced negative coefficients for August through November. This can be explained agronomically by the fact that Entre Rios is a very humid province with a high annual rainfall. Rainfall greater than the normal expected value produces disease and fungus problems, thereby reducing yield.

Working with variables chosen on the basis of correlation with yield failed to produce satisfactory results. Therefore, a mechanical process using SAS procedures was used to narrow down possible variables. The best model obtained was:

ETMETH5..............................May ET minus $\hat{ET}$
R6...................................June total precipitation
ZINDEX8..............................August Z index
R11..................................November total precipitation.

All coefficients were negative for June, August and November, indicating the less rain the better. The statistics of the selected model are summarized in Table 4. A plot of the model's predicted yields and the actual yields for 1950-1970 is shown in Figure 6.

La Pampa

For La Pampa, a plot of yield vs. year showed 1965 yield to be extraordinarily high--so high as to be questionable. Correlations and plots of variables with yield were more favorable without 1965. Therefore, 1965 was eliminated from the model data set. The best model had the following variables:

ETMETH4..............................April ET minus ET
TX8..................................August average maximum temperature
ETMETH9..............................September ET minus ET
P-PET10..............................October precipitation minus PET
P-PET11..............................November precipitation minus PET.

The problem with this and the other favorable models is that the coefficient for ETMETH4 was always negative. This cannot be explained agronomically. Therefore, the model was tried in the regression equation without ETHMETH4. The R2 was reduced, but all coefficients were reasonable. The coefficient for the August variable was the only negative. The statistics of the selected model are summarized in Table 5. A plot of the model's predicted yields and the actual yields for 1950-1970 is shown in Figure 7.

Santa Fe

For Santa Fe, 1964 was a year of outstanding yield. Eliminating 1964 from the data set produced better plots and correlations of weather variables to yield.

Santa Fe was the only province for which a satisfactory model was not obtained. Several different approaches were taken to derive a reasonable model, but the only acceptable model was the following:

ETMETH5............................May ET minus $\hat{ET}$
ETMETH7............................July ET minus $\hat{ET}$
ETMETH10..........................October ET minus $\hat{ET}$
ETMETH11..........................November ET minus $\hat{ET}$.

In this model, ETMETH10 was significant only at the 20 percent level. It was decided to keep it in the model to reflect conditions at the critical heading period in October. In addition, the R^2 for the model without ETMETH10 was lower. The only negative coefficient was for the November variable. This reflects the need for drier conditions at harvest time. The statistics of the selected model are summarized in Table 6. A plot of the model's predicted yields and the actual yields for 1950-1970 is shown in Figure 8.

TEST RESULTS

A bootstrap test was run on each model. In this test, the last year of the yield data set was left out and the model was used to predict yield for that year. This process was repeated for the number of years desired. In this case, the number of years used in the test for each province depended on the number of years with complete data. For Santa Fe this was nine years, for the other four provinces six.

For Buenos Aires, Entre Rios, and La Pampa the bootstrap test adequately predicted yields for 1971 through 1976. There were exceptions (a different year in each case) where the difference between predicted and actual yield was rather large. For Cordoba, the model predicted yield accurately for three out of the six years and rather poorly for two of the years. In 1972 there was a nine quintal per hectare difference between actual and predicted yield with the predicted yield the lower of the two. In that particular year the beginning of the growing season was extremely dry with increased moisture late in the season, enabling a come-back for the wheat. For Santa Fe, although the model showed actual and predicted yields running fairly close for the modeling years, the bootstrap test failed to predict within five quintals seven of the eight test years. Bootstrap results and plots of model results are printed beginning on page 15.

APPENDIX

Definition of Variables

Three types of indices were used to measure amount of moisture available for plant growth. The first, P-PET, is a measure of precipitation minus potential evapotranspiration. Potential evapotranspiration is determined by the procedures developed by Thornthwaite (1948). It requires temperature only:

$$PET = \left(\frac{10T}{I}\right)^a$$

where I = heat index, which is the sum of the 12 monthly indices i,

$$i = \left(\frac{T}{5}\right)^{1.514}$$

T = monthly temperature in °C, and

a = an empirical exponent = $6.75 \times 10^{-7} I^3 - 7.71 \times 10^{-5} I^2 + 1.79 \times 10^{-2} I + 0.49$.

The duration of daylight is used to adjust potential evapotranspiration as a portion of 12 hours.

The second index, Z index, is derived by an algorithm using monthly temperature and precipitation and is defined as

$$Z = dk$$

where $d = P - \hat{P}$ — P is the observed precipitation; $\hat{P}$ is the climatically appropriate precipitation and is equal to $\hat{ET} + \hat{R} + \hat{RO} + \hat{L}$.

Evapotranspiration $\hat{ET}$, recharge $\hat{R}$, runoff $\hat{RO}$, and loss $\hat{L}$ are obtained by multiplying each of their respective potential values (PET, PR, PRO, PL) by the coefficient which is the ratio of their average values to their average potential values; that is, $\alpha = \overline{ET}/\overline{PET}$, $\beta = \overline{R}/\overline{PR}$, $\gamma = \overline{RO}/\overline{PRO}$, and $\sigma = \overline{L}/\overline{PL}$. Climatically appropriate evapotranspiration, recharge, runoff, and loss are then determined as $\hat{ET} = \alpha \cdot PET$; $\hat{R} = \beta \cdot PR$; $\hat{RO} = \gamma \cdot PRO$; and $\hat{L} = \sigma \cdot PL$. Recharge, runoff, and loss are determined by a hydrologic procedure developed by Palmer (1965).

The third index is the difference between ET and $\hat{ET}$. 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 - ET measures the difference between the actual evapotranspiration and the "climatically appropriate" evapotranspiration, and hence gives 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 variables 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, and differs 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 temperatures 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 ET.

S T A T I S T I C A L   A N A L Y S I S   S Y S T E M   16:39 WEDNESDAY, NOV

BACKWARD ELIMINATION PROCEDURE FOR DEPENDENT VARIABLE YIELD

ALL VARIABLES ENTERED   R SQUARE = 0.87633601   C(P) = 6.00000000

	DF	SUM OF SQUARES	MEAN SQUARE	F	PROB>F
REGRESSION	5	84.53533563	16.90706713	21.26	0.0001
ERROR	15	11.92918418	0.79527921		
TOTAL	20	96.46452381			

	B VALUE	STD ERROR	TYPE II SS	F	PROB>F
INTERCEPT	20.95565645				
TREND	0.27255560	0.04899149	24.61436006	30.95	0.0001
ETMETH4	0.27623307	0.03967002	38.56080320	48.49	0.0001
R7	-0.03932946	0.01131750	9.60404949	12.08	0.0034
ZINDEX8	0.03268848	0.00680040	18.37554505	23.11	0.0002
TX9	-0.43245258	0.15058974	6.55851999	8.25	0.0116

LES IN THE MODEL ARE SIGNIFICANT AT THE 0.1000 LEVEL.

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Table 2. Statistics of Model for Province of Buenos Aires.

STATISTICAL ANALYSIS SYSTEM 16:40 WEDNESDAY, NO

BACKWARD ELIMINATION PROCEDURE FOR DEPENDENT VARIABLE YIELD

ALL VARIABLES ENTERED   R SQUARE = 0.69480993   C(P) = 5.00000000

	DF	SUM OF SQUARES	MEAN SQUARE	F	PROB>F
REGRESSION	4	134.31096736	33.57774184	9.11	0.0005
ERROR	16	58.99508978	3.68719311		
TOTAL	20	193.30605714			

	B VALUE	STD ERROR	TYPE II SS	F	PROB>F
INTERCEPT	21.03908139				
ETMETH5S	-0.01842795	0.01016689	12.11359933	3.29	0.0887
TX7	-0.42395604	0.21786867	13.96201152	3.79	0.0694
P PET8	0.09700964	0.02912134	40.91690661	11.10	0.0042
ETMET90S	-0.00982928	0.00294987	40.93871412	11.10	0.0042

LES IN THE MODEL ARE SIGNIFICANT AT THE 0.1000 LEVEL.

Table 3. Statistics of Model for Province of Cordoba.

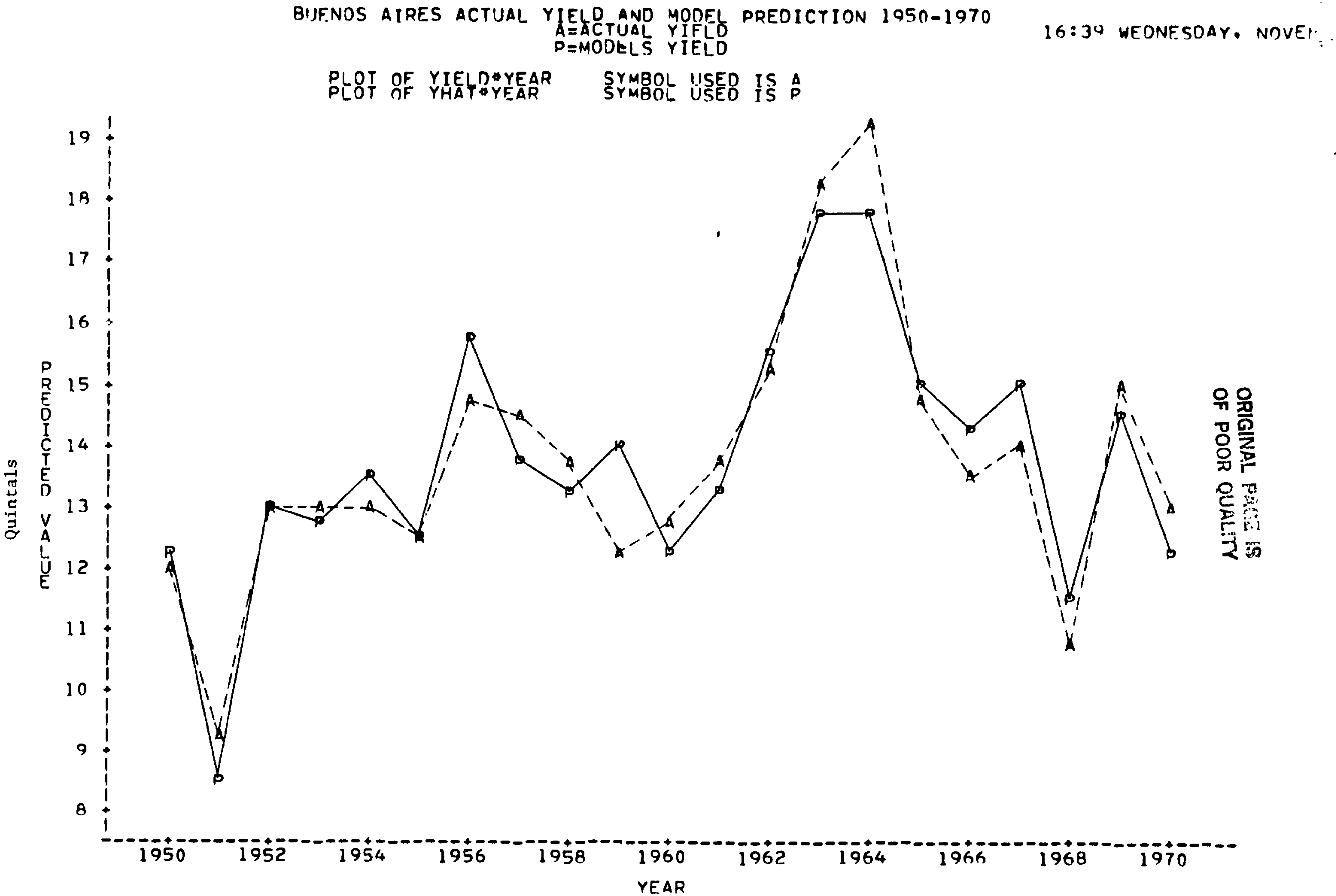

Figure 4. Province of Buenos Aires Wheat Model.

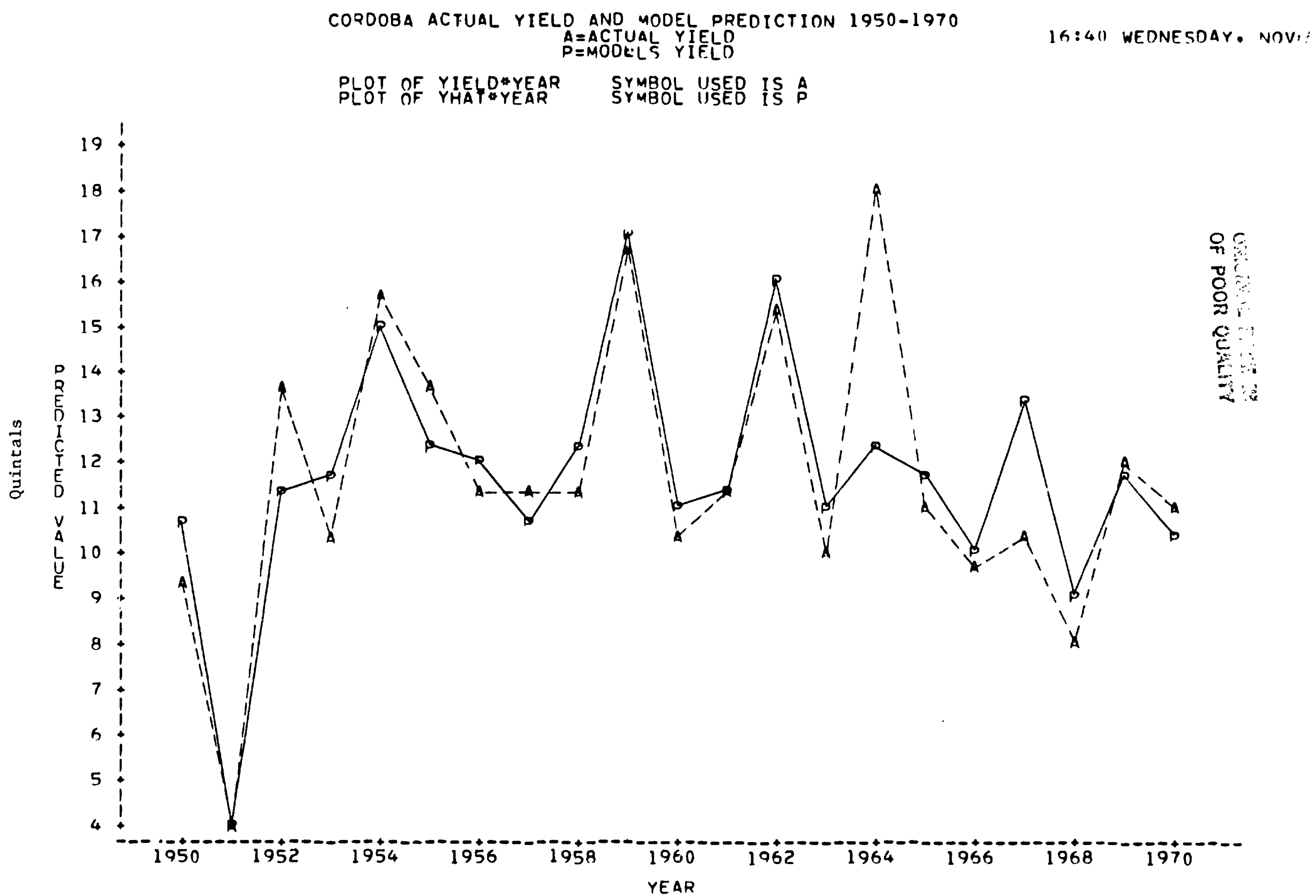

Figure 5. Province of Cordoba Wheat Model.

BACKWARD ELIMINATION PROCEDURE FOR DEPENDENT VARIABLE YIELD

ALL VARIABLES ENTERED R SQUARE = 0.55630508 C(P) = 5.00000000

	DF	SUM OF SQUARES	MEAN SQUARE	F	PROB>F
REGRESSION	4	55.67871662	13.91967915	5.22	0.0069
ERROR	16	42.64057862	2.66503616		
TOTAL	20	98.31929524			

	B VALUE	STD ERROR	TYPE II SS	F	PROB>F
INTERCEPT	13.67199915				
ETMETHS	0.21835878	0.09884839	15.10861991	5.67	0.0300
R6	-0.02359826	0.00830197	21.47862351	8.06	0.0114
ZTMOF*R8	-0.01883662	0.00847562	10.51646174	3.95	0.0644
R11	-0.01583371	0.00721486	12.83570670	4.82	0.0433

LES IN THE MODEL ARE SIGNIFICANT AT THE 0.1000 LEVEL.

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Table 4. Statistics of Model for Province of Entre Rios.

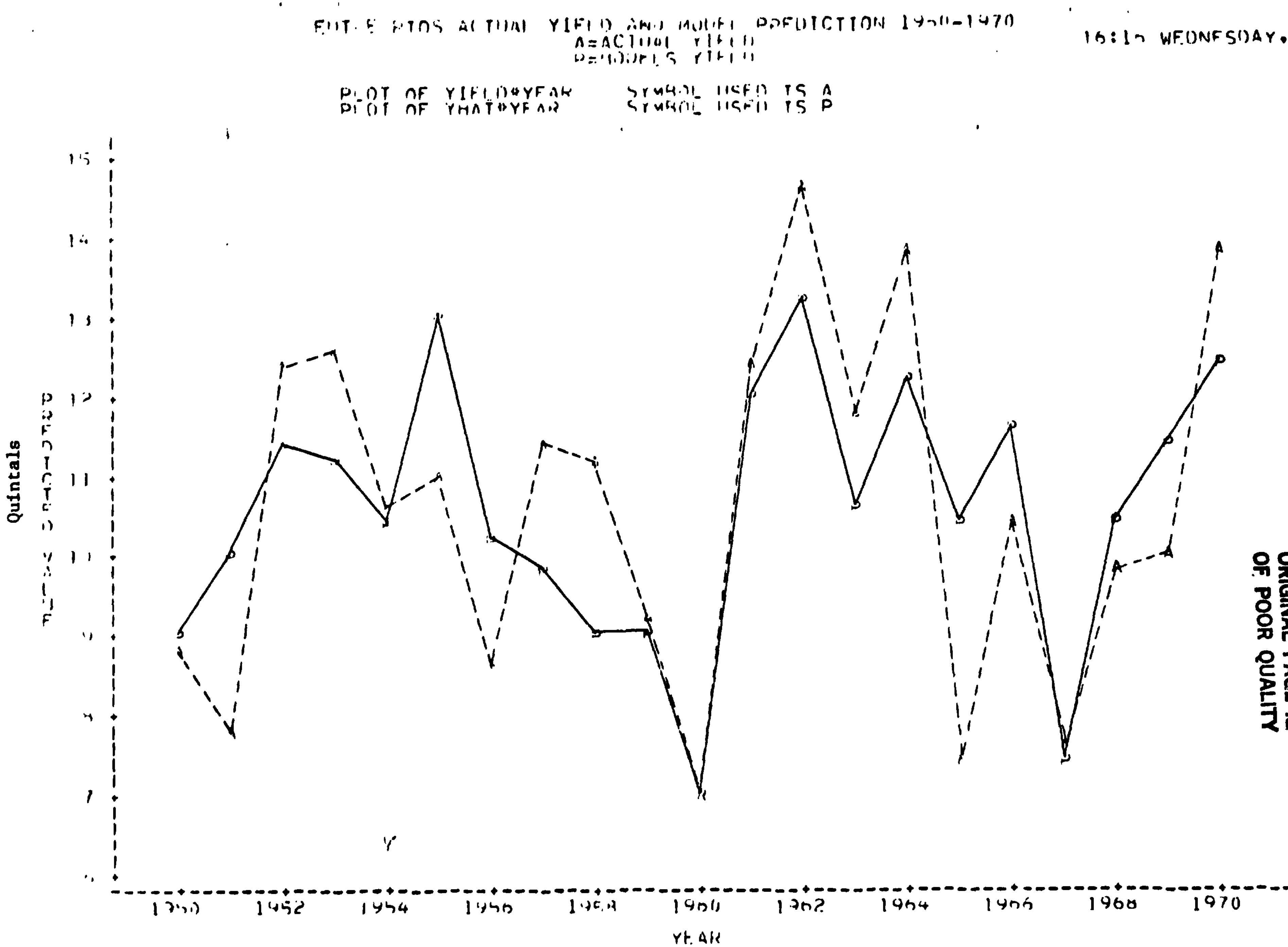

Figure 6. Province of Entre Rios Wheat Model.

S T A T I S T I C A L   A N A L Y S I S   S Y S T E M

BACKWARD ELIMINATION PROCEDURE FOR DEPENDENT VARIABLE YIELD

ALL VARIABLES ENTERED   R SQUARE = 0.73086214   C(P) = 5.00000000

	DF	SUM OF SQUARES	MEAN SQUARE	F	PROB>F
REGRESSION	4	117.55930273	29.38982568	10.18	0.0001
ERROR	15	43.29087227	2.88605815		
TOTAL	19	160.85017500			

	B VALUE	STD ERROR	TYPE II SS	F	PROB>F
INTERCEPT	31.44003043				
TXR	-1.28377470	0.38060416	32.82454518	11.37	0.0042
ETMETH9	0.24140295	0.08719319	22.12203341	7.67	0.0143
P PET10	0.02426685	0.00959265	18.46949524	6.40	0.0231
P PET11	0.03623129	0.01036522	35.26269506	12.22	0.0033

RLES IN THE MODEL ARE SIGNIFICANT AT THE 0.1000 LEVEL.

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Table 5. Statistics of Model for Province of La Pampa.

LA PAMPA ACTUAL YIELD AND MODEL PREDICTION 1950-1970
A=ACTUAL YIELD
P=MODELS YIELD

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PLOT OF YIELD*YEAR   SYMBOL USED IS A
PLOT OF YHAT*YEAR   SYMBOL USED IS P

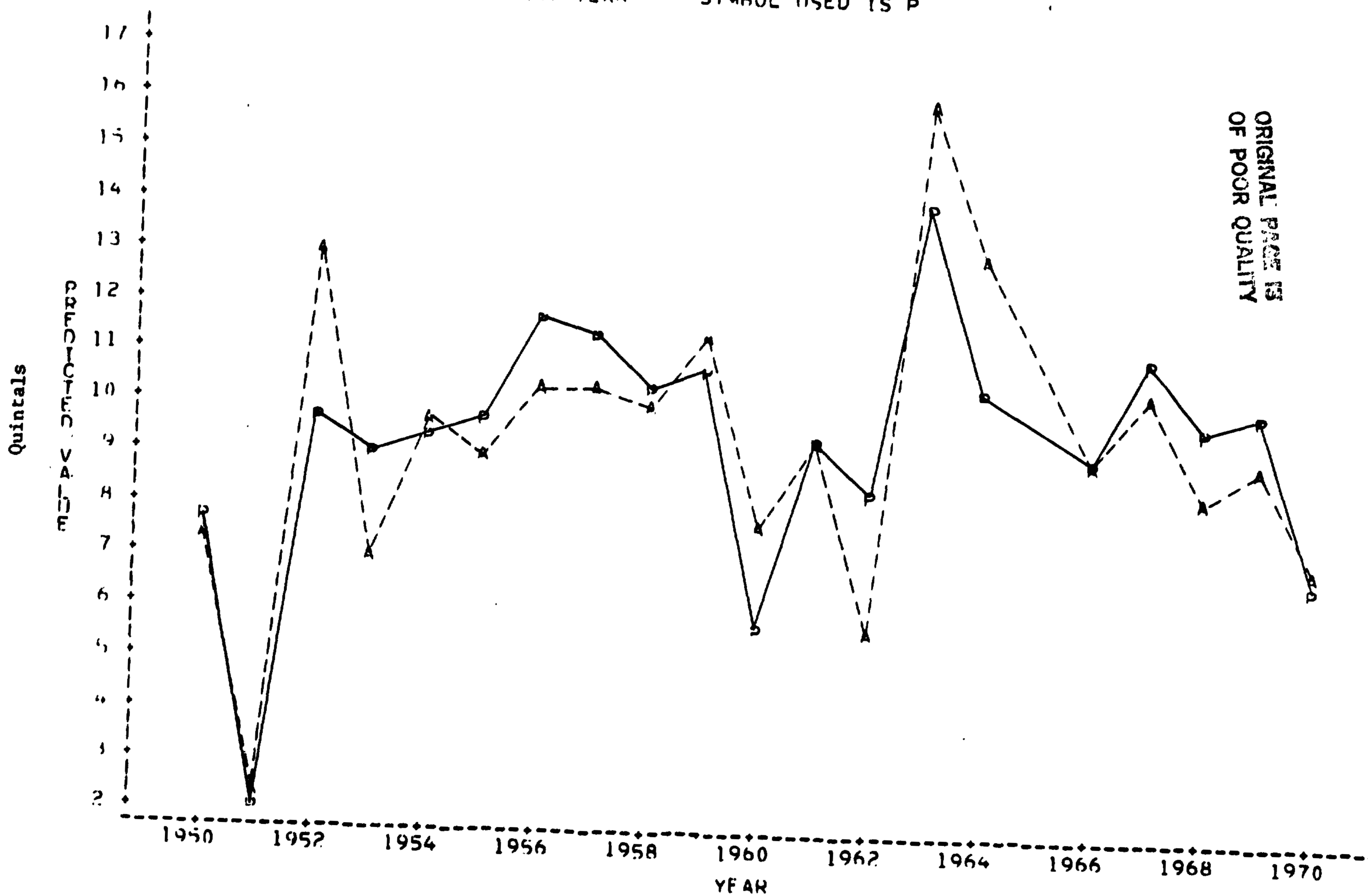

Figure 7. Province of La Pampa Wheat Model.

STATISTICAL ANALYSIS SYSTEM 16:42 WEDNESDAY, NOV

BACKWARD ELIMINATION PROCEDURE FOR DEPENDENT VARIABLE YIELD

ALL VARIABLES ENTERED — R SQUARE = 0.73525485 — C(P) = 5.00000000

	DF	SUM OF SQUARES	MEAN SQUARE	F	PROB>F
REGRESSION	4	121.96626241	30.49156560	10.41	0.0003
ERROR	15	43.91671259	2.92778084		
TOTAL	19	165.88297500			

	B VALUE	STD ERROR	TYPE II SS	F	PROB>F
INTERCEPT	14.21633800				
ETMETH5	0.18631292	0.07845809	16.51007703	5.64	0.0313
ETMETH7	1.58218278	0.32315203	70.18399707	23.97	0.0002
ETMETH10	0.16074098	0.12027388	5.22936706	1.79	0.2013
ETMETH11	-0.55618748	0.22924733	17.23496053	5.89	0.0283

VARIABLE ETMETH10 REMOVED — R SQUARE = 0.70373042 — C(P) = 4.78611971

	DF	SUM OF SQUARES	MEAN SQUARE	F	PROB>F
REGRESSION	3	116.73689535	38.91229845	12.67	0.0002
ERROR	16	49.14607965	3.07162998		
TOTAL	19	165.88297500			

	B VALUE	STD ERROR	TYPE II SS	F	PROB>F
INTERCEPT	14.21688607				
ETMETH5	0.16821294	0.07915607	13.87136650	4.52	0.0495
ETMETH7	1.57050198	0.33087439	69.20214824	22.53	0.0002
ETMETH11	-0.63741900	0.22639741	24.34871304	7.93	0.0124

LES IN THE MODEL ARE SIGNIFICANT AT THE 0.1000 LEVEL.

Table 6. Statistics of Model for Province of Santa Fe.

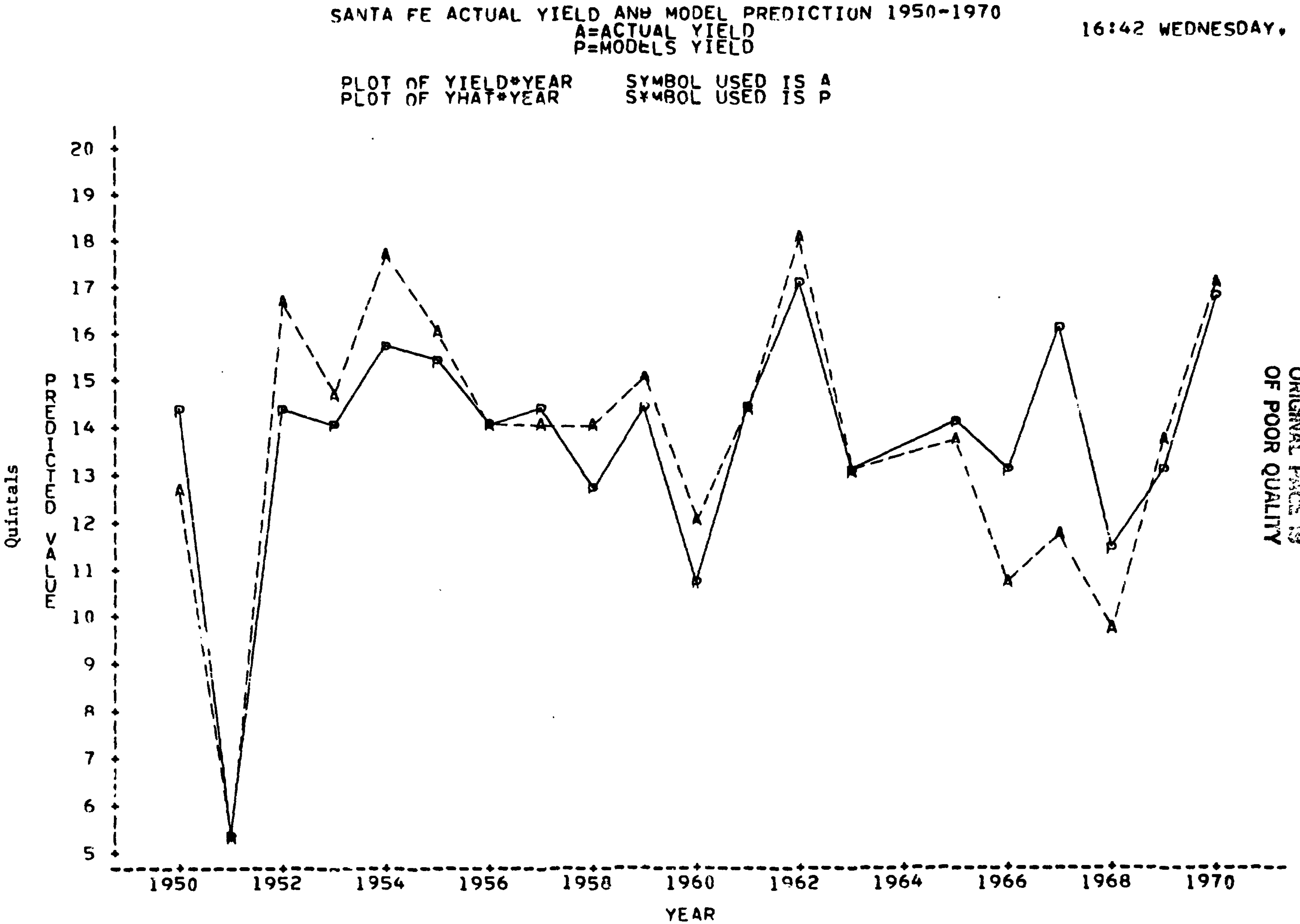

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Figure 8. Province of Santa Fe Wheat Model.

S T A T I S T I C A L   A N A L Y S I S   S Y S T E M   15:54 MONDAY, JANUARY

BETA2	BEGMDLYR	ENDMDLYR	YIELDYR	YIELD	OBSYIELD	RSQ	PDER	DFRES	MSRES	BETA1
0.273318	1950	1969	1970	11.9285	13.0[illegible]	0.882743	0.54131	14	0.80310	22.2659
0.272556	1950	1970	1971	17.3248	12.7[illegible]	0.876336	0.35325	15	0.79528	20.9557
0.260020	1950	1971	1972	13.8520	17.94	0.729944	0.33872	16	1.64340	22.4011
0.298489	1950	1972	1973	14.4450	16.08	0.649591	0.41539	17	2.36177	23.48[illegible]
0.314440	1950	1973	1974	12.8539	14.56	0.644128	1.23286	18	2.35686	23.5306
0.336092	1950	1974	1975	15.4460	14.59	0.629124	0.27583	19	2.33339	24.2570
0.332449	1950	1975	1976	16.8701	17.01	0.624703	0.94960	20	2.24949	24.4320

BETA3	BETA4	BETA5	BETA6	CONRIB1	CONRIB2	CONRIB3	CONRIB4	CONRIB5	CONRIB6
0.27728[illegible]	-0.038817	0.0345076	-0.50808	22.2659	3.55313	0.0183	-0.7763	-2.0056	-11.127
0.276233	-0.0393[illegible]	0.0326485	-0.43245	20.9557	3.54322	0.6268	-1.4552	2.0871	-8.433
0.244091	-0.02969[illegible]	0.0187551	-0.53898	22.4011	3.38026	-1.3892	-0.6236	0.1625	-10.079
0.208360	-0.038418	0.0204974	-0.58838	23.4880	3.88035	0.5547	-1.4599	-0.9567	-11.061
0.210257	-0.036872	0.017745[illegible]	-0.59889	23.5306	4.08771	-2.3520	-2.1754	0.0041	-10.241
0.183264	-0.032536	0.0162190	-0.65615	24.2570	4.36920	0.5640	-0.8785	-0.0052	-12.861
0.179219	-0.031342	0.0157948	-0.66829	24.4320	4.32184	0.4772	-1.0970	1.3668	-12.631

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Table 7. Results of Jackknife Test for Buenos Aires Wheat Model.

BUENOS AIRES BOOTSTRAP RESULTS--TEST OF MODEL 1970-1976
O=OBSERVED YIELD
P=MODELS PREDICTED YIELD

16:39 WEDNESDAY, NOVEM

PLOT OF YIELD*YIELDYR   SYMBOL USED IS P
PLOT OF OBSYIELD*YIELDYR   SYMBOL USED IS O

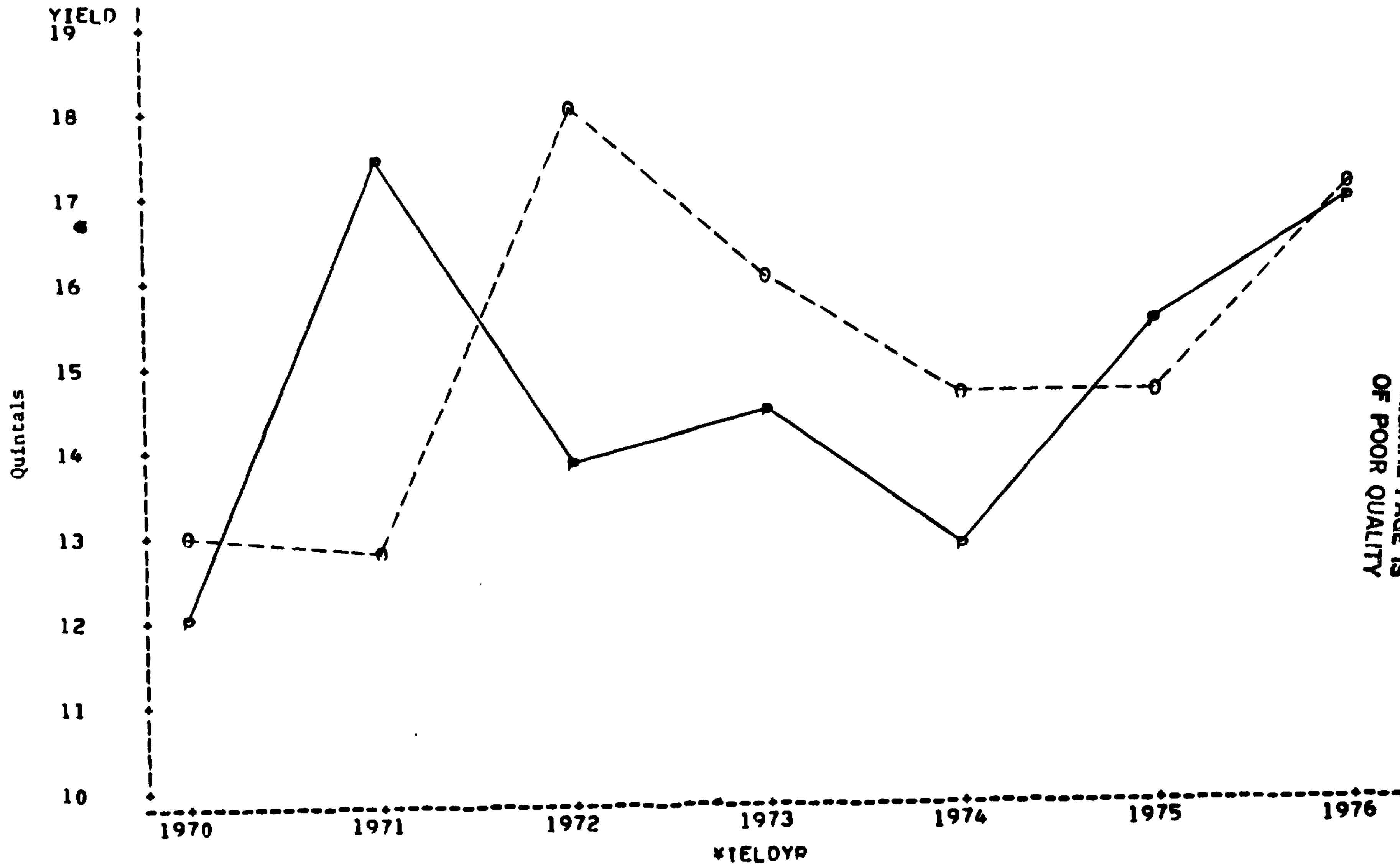

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Figure 9. Province of Buenos Aires Wheat Model.

S T A T I S T I C A L   A N A L Y S I S   S Y S T E M   16:04 MONDAY, JANUAR

BETA1	BEGMOLYR	ENDMOLYR	YIELDYR	YIELD	OBSYIELD	RSQ	PDER	DFRES	MSRES
21.3036	1950	1969	1970	10.2936	10.97	0.696043	0.8217	15	3.90781
21.0391	1950	1970	1971	11.2243	12.66	0.694810	0.6923	16	3.68719
20.3375	1950	1971	1972	3.0911	12.46	0.687466	31.3341	17	3.57238
20.7486	1950	1972	1973	12.7286	19.25	0.642312	1.0233	18	3.87298
24.5507	1950	1973	1974	12.8760	14.22	0.585519	0.2716	19	5.43956
24.6416	1950	1974	1975	16.0393	20.76	0.586285	1.4946	20	5.25360
26.0842	1950	1975	1976	18.6413	18.70	0.624300	3.0951	21	5.82961

BETA2	BETA3	BETA4	BETA5	CONRIB1	CONRIB2	CONRIB3	CONRIB4	CONRIB5	RUN
-0.017972	-0.44128	0.099569	-0.009637	21.3036	-0.171	-7.987	-2.8389	-0.01302	
-0.018428	-0.42346	0.097010	-0.009429	21.0391	-0.210	-8.182	-1.4189	-0.00368	
-0.019393	-0.37591	0.096163	-0.010234	20.3375	-11.446	-6.127	0.5726	-0.24546	
-0.004613	-0.42195	0.098008	-0.009615	20.7486	-0.062	-5.317	-2.5942	-0.04692	
-0.004717	-0.64690	0.083075	-0.009347	24.5507	-0.096	-10.544	-0.9408	-0.09371	
-0.004858	-0.64788	0.083685	-0.009465	24.6416	-0.068	-9.913	1.4758	-0.09804	
-0.006079	-0.70276	0.109747	-0.009471	26.0842	-0.089	-11.455	4.3213	-0.22046	

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Table 8. Results of Jackknife Test for Cordoba Wheat Model.

CORDOBA BOOTSTRAP RESULTS--TEST OF MODEL 1970-1976
O=OBSERVED YIELD
P=MODELS PREDICTED YIELD

16:40 WEDNESDAY, NOVEM

PLOT OF YIELD*YIELDYR SYMBOL USED IS P
PLOT OF OBSYIELD*YIELDYR SYMBOL USED IS O

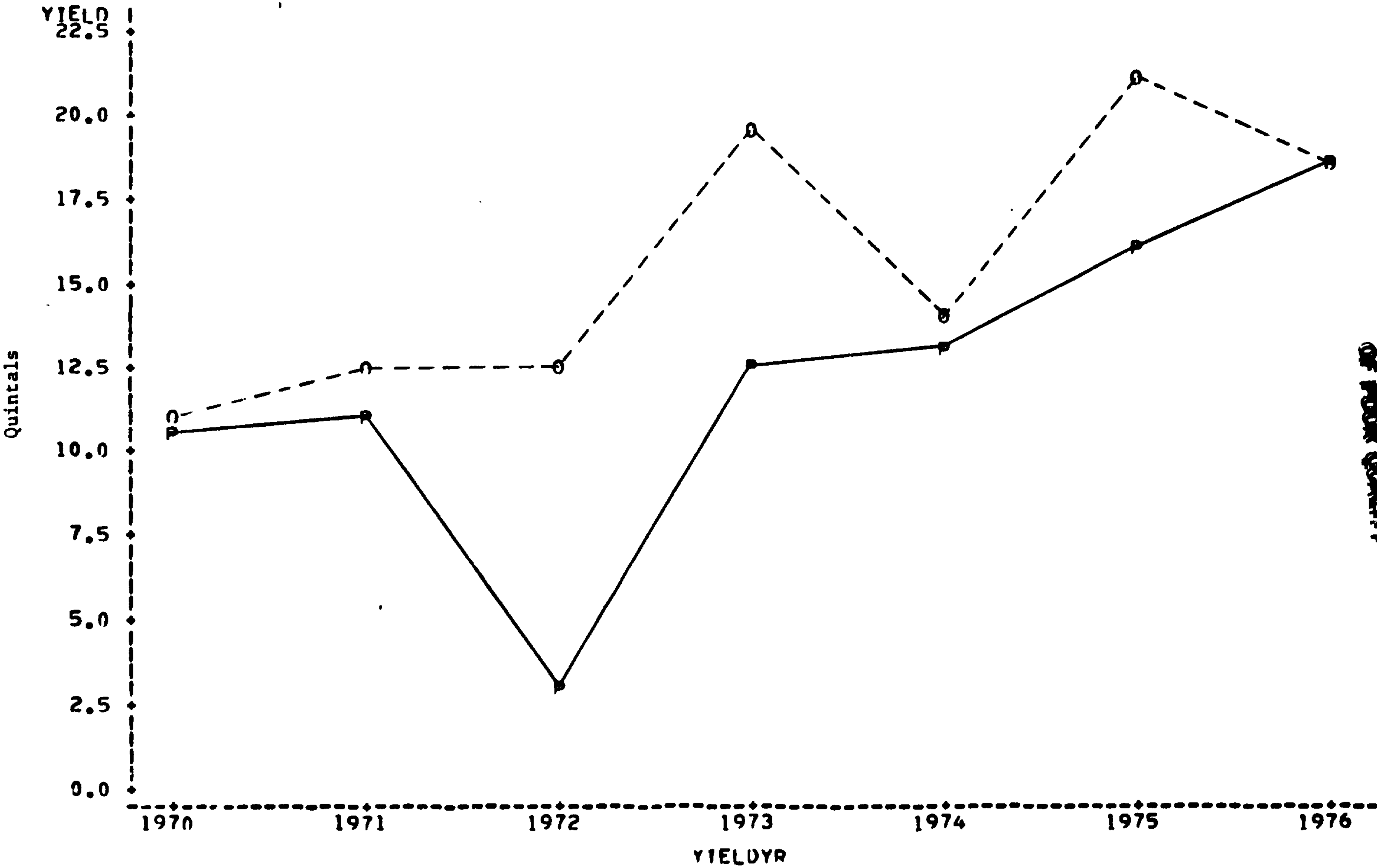

Figure 10. Province of Cordoba Wheat Model.

STATISTICAL ANALYSIS SYSTEM 16:05 MONDAY, JANUARY

BETA1	BEGMDLYR	ENDMDLYR	YIELDYR	YIELD	OBSYIELD	RSQ	PDER	DFRES	MSRES
13.1074	1950	1969	1970	11.9279	13.88	0.542517	0.779399	15	2.64646
13.6720	1950	1970	1971	11.6037	10.28	0.566305	0.200225	16	2.66504
13.5213	1950	1971	1972	9.3563	9.75	0.550081	0.265945	17	2.60414
13.5087	1950	1972	1973	11.1969	16.11	0.551444	0.527053	18	2.46728
13.8541	1950	1973	1974	11.2683	11.39	0.501534	0.223651	19	3.39424
13.8674	1950	1974	1975	10.6576	11.67	0.502949	0.208652	20	3.21572

BETA2	BETA3	BETA4	BETA5	CONRIB1	CONRIB2	CONRIB3	CONRIB4	CONRIB5	RU
0.226697	-0.021511	-0.017539	-0.012625	13.1074	0.152195	-0.6668	-0.36186	-0.3030	
0.235359	-0.023558	-0.016837	-0.015834	13.6720	0.114802	-0.6835	0.09960	-1.5992	
0.233480	-0.022593	-0.016823	-0.015527	13.5213	0.191097	-1.8978	-0.56396	-1.8943	
0.234126	-0.022390	-0.016499	-0.015358	13.5087	0.136659	-2.2838	0.72615	-0.8908	
0.271868	-0.017752	-0.022657	-0.019595	13.8541	0.200865	-0.9591	-0.29909	-1.5284	
0.272207	-0.017796	-0.022621	-0.019654	13.8674	0.191825	-1.3347	-0.49450	-1.5723	

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Table 9. Results of Jackknife Test for Entre Rios Wheat Model.

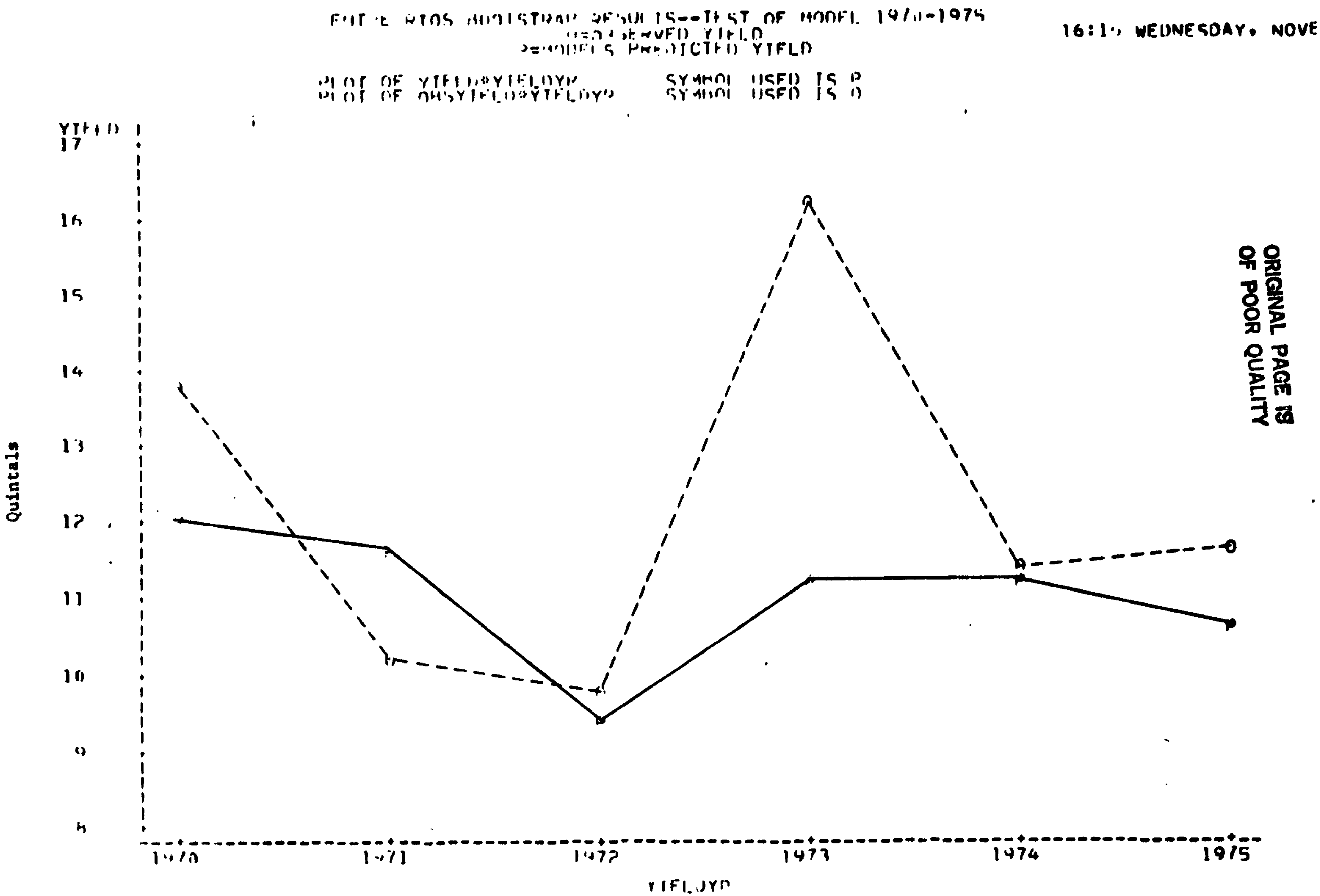

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Figure 11. Province of Entre Rios Wheat Model.

STATISTICAL ANALYSIS SYSTEM 15:55 WEDNESDAY, JAN

BETA1	BEGMDLYR	ENDMDLYR	YIELDYR	YIELD	OBSYIELD	RSQ	PDER	DFRES	MSRES
31.8719	1950	1969	1970	5.7078	7.05	0.722488	0.68200	14	3.08536
31.4400	1950	1970	1971	6.5516	8.36	0.730862	1.26036	15	2.88606
27.7852	1950	1971	1972	15.8634	11.62	0.672965	2.26159	16	3.30393
24.7286	1950	1972	1973	9.9817	13.73	0.619674	1.50110	17	3.73838
23.3297	1950	1973	1974	5.5260	10.40	0.603473	2.47813	18	4.08761
20.2757	1950	1974	1975	7.9531	11.76	0.447102	0.75036	19	5.42076
19.6289	1950	1975	1976	13.8358	13.75	0.393815	2.03750	20	5.78623

BETA2	BETA3	BETA4	BETA5	CONRIB1	CONRIB2	CONRIB3	CONRIB4	CONRIB5	RUNNUM
-1.3102	0.[illegible]1107	0.0242073	0.0[illegible]1695	31.8719	-24.239	0.2125	0.1892	-1.3272	1
-1.2638	0.[illegible]1403	0.0242669	0.0[illegible]2413	31.4400	-24.135	1.0902	-0.2068	-3.5369	2
-1.0680	0.[illegible]38	0.0222914	0.0[illegible]7881	27.7852	-15.806	1.0252	-0.1479	3.0072	3
-0.9049	0.[illegible]18136	0.0233982	0.0[illegible]7453	24.7286	-16.288	0.2964	2.3504	-1.1061	4
-0.8143	0.1[illegible]6692	0.0316790	0.0200316	23.3297	-15.065	-2.6004	-1.1147	-1.0173	5
-0.6159	0.060[illegible]32	0.0302610	0.0176467	20.2757	-10.717	0.2503	-1.1454	-0.7101	6
-0.5715	0.0[illegible]1264	0.025[illegible]53	0.01[illegible]841	19.6289	-8.630	0.3478	1.0058	1.4832	7

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Table 10. Results of Jackknife Test for La Pampa Wheat Model.

LA PAMPA BOOTSTRAP RESULTS--TEST OF MODEL 1970-1976 15:15 WEDNESDAY, J

O=OBSERVED YIELD

P=MODELS PREDICTED YIELD

PLOT OF YIELD*YIELDYR SYMBOL USED IS P

PLOT OF OBSYIELD*YIELDYR SYMBOL USED IS O

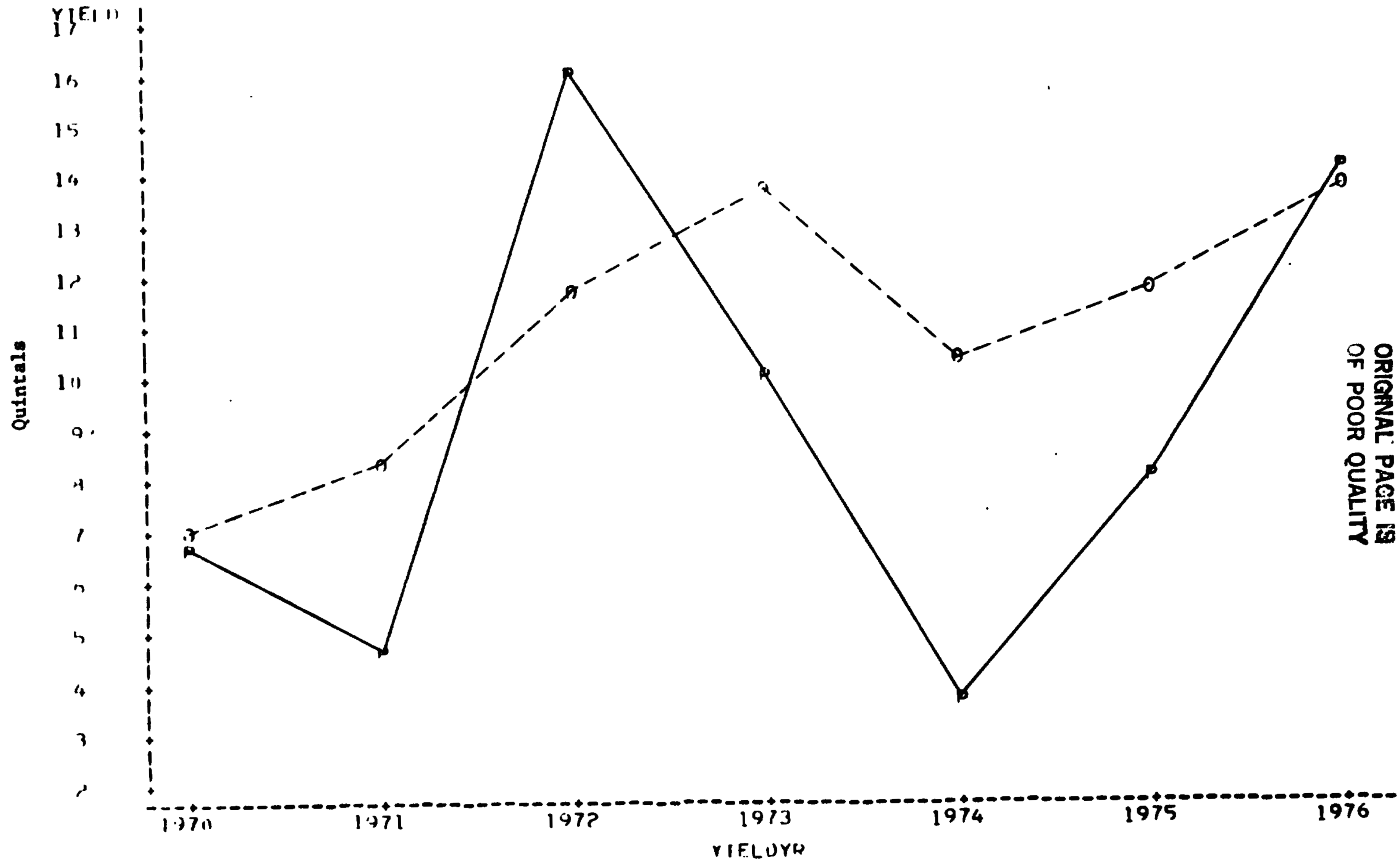

Figure 12. Province of La Pampa Wheat Model.

BETA1	BEGMDLYR	ENDMDLYR	YIELDYR	YIELD	OBSYIELD	RSQ	PDER	DFRES	MSRES
14.1592	1950	1969	1970	16.4210	17.03	0.716705	0.8074	14	3.11587
14.2163	1950	1970	1971	16.0666	14.92	0.735255	0.3717	15	2.92778
14.1362	1950	1971	1972	10.2094	15.36	0.730648	2.4984	16	2.81771
14.3034	1950	1972	1973	14.1556	19.27	0.651933	0.3327	17	3.47907
14.4530	1950	1973	1974	23.0585	15.93	0.581830	28.7969	18	4.61214
14.1349	1950	1974	1975	15.5238	23.01	0.554188	0.6271	19	4.73861
14.4251	1950	1975	1976	15.2377	20.14	0.497853	0.5433	20	6.97634
14.6165	1950	1976	1977	10.9645	16.41	0.475850	1.8411	21	7.70584
14.8090	1950	1977	1978	15.2686	20.15	0.403816	0.5976	22	8.44353

BETA2	BETA3	BETA4	BETA5	CONRIB1	CONRIB2	CONRIB3	CONRIB4	CONRIB5	RUNNU
0.184269	1.57831	0.159807	-0.52689	14.1592	0.4179	0.5704	0.173735	1.09979	1
0.196313	1.58218	0.160741	-0.55619	14.2163	0.3321	0.7278	0.186060	0.60432	2
0.183307	1.56932	0.156522	-0.52575	14.1362	-3.6012	0.4703	0.171979	-0.96796	3
0.071430	1.59038	0.154560	-0.49395	14.3034	0.1431	0.3945	0.182597	-0.86797	4
0.092649	1.65130	0.207117	-0.39258	14.4530	0.2455	0.7704	0.232404	7.35729	5
0.101803	1.69138	0.245107	-0.07712	14.1349	0.2667	0.3947	0.263641	0.46387	6
0.116084	1.69732	0.265626	-0.16421	14.4251	0.2534	0.5743	0.301179	-0.31638	7
0.133845	1.75903	0.304299	-0.13342	14.6165	-0.3004	-3.8724	0.427799	0.09300	8
0.120422	1.40480	0.330620	-0.14880	14.8090	-0.2973	0.6646	0.410640	-0.31828	9

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Table 11. Results of Jackknife Test for Santa Fe Wheat Model.

SANTA FE BOOTSTRAP RESULTS--TEST OF MODEL 1970-1978
O=OBSERVED YIELD
P=MODELS PREDICTED YIELD

16:42 WEDNESDAY, NOVE

PLOT OF YIELD*YIELDYR SYMBOL USED IS P
PLOT OF OBSYIELD*YIELDYR SYMBOL USED IS O

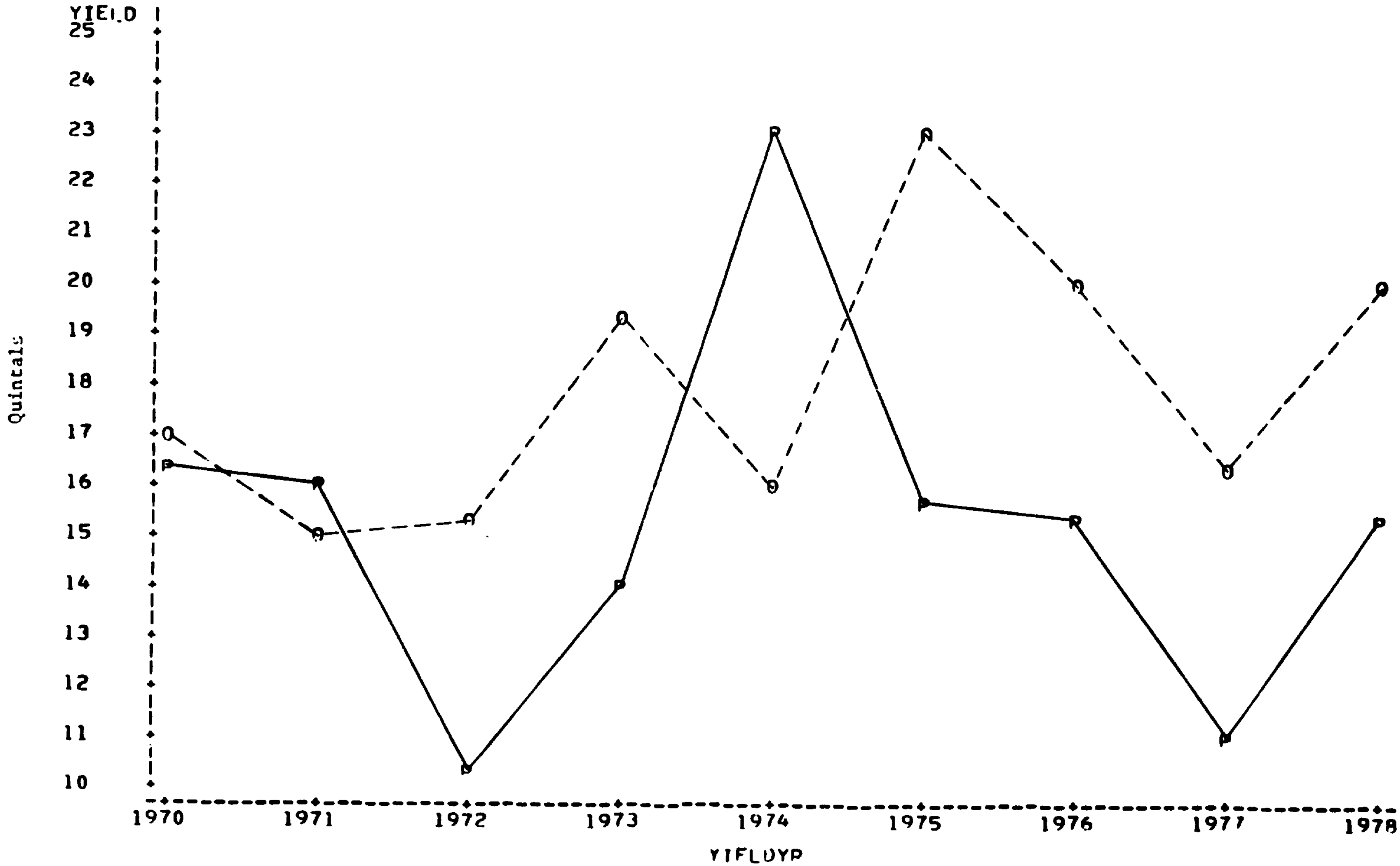

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Figure 13. Province of Santa Fe Wheat Model.